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Design and Performance of Small
Hammer Feed Mills *F. W. Duffee*

Hill Planting and Checker Cultivation
of Cotton *J. O. Ware*

Supplemental Water for Irrigation
Purposes *H. A. Brown*

Tests of a Commercial Sweet Potato
Storage House *M. A. R. Kelley*

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No. 5

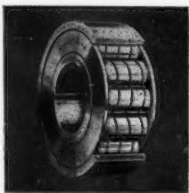
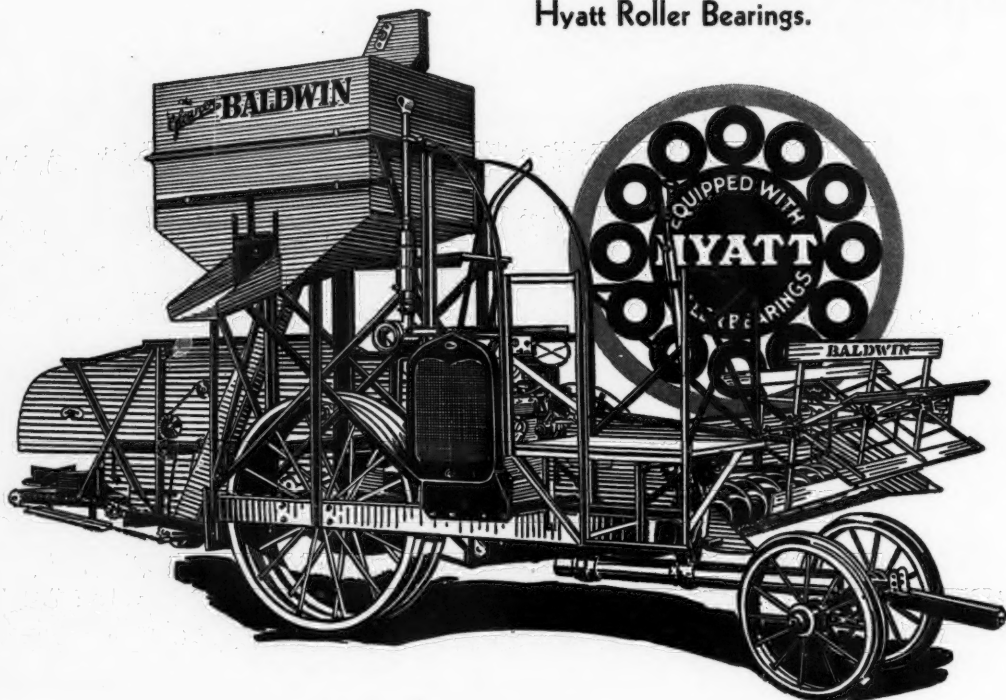
CONTENTS

THE DESIGN AND PERFORMANCE OF SMALL HAMMER-TYPE FEED MILLS	171
By F. W. Duffee	
THE HILL PLANTING OF COTTON AND CHECKER CULTIVATION WITH LARGE TILLAGE IMPLEMENTS	177
By J. O. Ware	
PROVIDING SUPPLEMENTAL WATER FOR IRRIGATION	179
By Hugh A. Brown	
TEST OF A COMMERCIAL SWEET POTATO STORAGE HOUSE	181
By M. A. R. Kelley	
PORTABLE DAIRY COOLERS	185
By H. C. Parker	
A TEMPERATURE STUDY OF DAIRY BARN FLOORS	187
By Roy Bainer	
THE COST OF FARM BUILDINGS	190
By Deane G. Carter	
AGRICULTURAL ENGINEERING DIGEST	192
WHO'S WHO IN AGRICULTURAL ENGINEERING	195
EDITORIALS	196
A.S.A.E. AND RELATED ACTIVITIES	197

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No. 5

The Design and Performance of Small Hammer-Type Feed Mills¹

By F. W. Duffee²

THIS paper deals with small mills for electric operation, and the results and conclusions should not be taken as necessarily applying to larger mills. The object of this report is twofold: (1) To supply information relative to the performance of small hammer type feed mills, and (2) to explain some of the factors involved in their design.

Our work on small feed mills has been done largely in connection with the Wisconsin Project on the Application of Electricity to Agriculture. The project was established in February, 1924. Very shortly thereafter some fifteen small mills were secured and tested out in a rather general way by E. R. Meacham. All of these were burr mills, except one.

Out of this group three or four of the most satisfactory and efficient were selected for installation on the Ripon experimental electric line. These were all burr mills. The performance of only one of the entire group was fairly satisfactory in actual farm service. The others gave trouble in a very short time. They did not stand up in service, the burrs dulled quickly, becoming very inefficient, and foreign material in the grain was disastrous to the mill, in one case resulting in ruining a new leather belt.

These mills were unsatisfactory with an attendant present, and it was obvious that still greater trouble would be encountered if the mills were automatic, which is almost necessary to be practical, due to the comparatively slow rate of grinding.

In the fall of 1926 a small hammer mill was secured by W. C. Krueger and placed on one of the farms of the

Ripon line. This was a second-hand mill, and had seen considerable service prior to this installation. This mill quickly demonstrated a very satisfactory and efficient performance on the farm in grinding for some 15 or 20 head of cattle. The mill has been in continuous service since installed, is operated by a 5-hp. motor, with the mill running at 4500 r.p.m., and there have been no repairs made on it to our knowledge.

The principal objection to this machine was the price (about \$170.00 for the mill without a fan), which obviously made it out of the question for general farm service under the particular conditions. Another objection to the mill was the lack of a satisfactory feeding device which could be easily regulated. The feeder consisted of a sloping trough into the mill which could be sloped at different angles to regulate the rate of feeding, a very unsatisfactory affair.

During the winter of 1926, a Wisconsin manufacturer became interested in developing a small hammer type mill similar to the one referred to above, but equipped with a suitable feeding device, a fan, and priced more in line with other agricultural machinery. About the same time, another manufacturer began a similar development independent of our work. These mills, with others, were tested by Krueger during the winter of 1926-27. This work together with a summary of the previous work was reported in July 1927 number of AGRICULTURAL ENGINEERING.

Developmental and testing work has been carried on to some extent continuously since 1926, with the result that there are to our knowledge three or four makes of small hammer mills on the market at the present time, and another will be out soon.

These mills are now very satisfactory and dependable in performance, easy to operate and regulate, both as to the rate of grinding and the fineness of grinding. They are proving to be durable, economical and satisfactory in every respect, except for grinding corn on the cob, and

¹Paper presented at a meeting of the Rural Electric Division of the American Society of Agricultural Engineers, Chicago, December, 1929. Reprinting of extracts from this report is forbidden, in view of the fact that certain statements, when considered alone, might be construed as being favorable to some particular machine, whereas the complete report will not warrant this conclusion.

²Associate professor of agricultural engineering, University of Wisconsin. Mem. A.S.A.E.

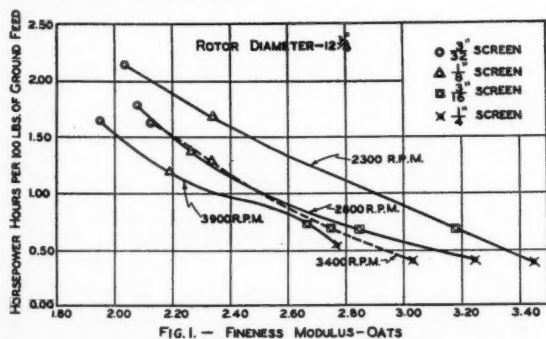


FIG. 1. — FINENESS MODULUS — OATS

Fig. 1. These curves show the relation between mill speed, fineness of grinding, and efficiency. Approximately a 5-hp. load was maintained throughout, except for the $\frac{1}{2}$ -inch screen at the two lower speeds, where the fan would not elevate at full 5 hp. capacity

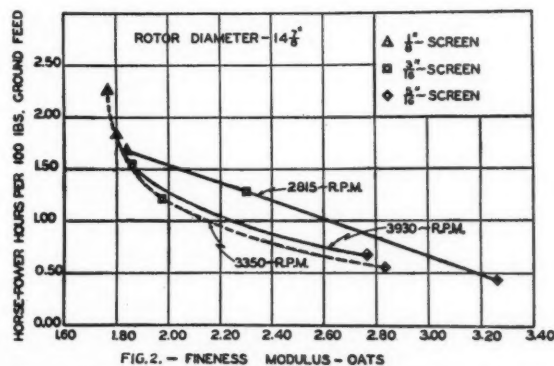


FIG. 2. — FINENESS MODULUS — OATS

Fig. 2. These curves show the relation between mill speed, fineness of grinding, and efficiency. Approximately a 5-hp. load was maintained throughout, except for the $\frac{1}{4}$ -inch screen at 2815 r.p.m. where the fan would not elevate at full 5 hp. capacity

Size of screen openings, in.	Speed of mill, r.p.m.	Corn				Oats				Barley			
		Pounds per hour	Avg. efficiency, %	Sp.-hr. per 100 lb.	Power, hp.	Pounds per hour	Avg. efficiency, %	Sp.-hr. per 100 lb.	Power, hp.	Pounds per hour	Avg. efficiency, %	Sp.-hr. per 100 lb.	Power, hp.
1/8	3350	745	9.12	1.74	0.750	300	5.10	1.79	1.701	455	5.19	3.48	1.223
3/8	3350	1250	8.97	2.15	0.454	555	5.18	2.33	0.899	755	5.08	2.43	0.771
1/4	3350	1580	8.05	2.59	0.384	900	5.07	2.74	0.559	—	—	—	—
3/4	3350	1605	4.93	2.57	0.303	1095	5.36	2.90	0.490	1150	5.08	3.77	0.435

NOTE 1. The modulus for the 3/8-inch screen on corn is finer than on the 1/4-inch screen, probably due to lighter feeding in proportion to the screen size. This was necessary due to the inability of the fan to handle more material.

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Size of screen openings, in.	Speed of mill, r.p.m.	Corn				Oats				Barley			
		Pounds per hour	Avg. efficiency, %	Sp.-hr. per 100 lb.	Power, hp.	Pounds per hour	Avg. efficiency, %	Sp.-hr. per 100 lb.	Power, hp.	Pounds per hour	Avg. efficiency, %	Sp.-hr. per 100 lb.	Power, hp.
1/8	3350	990	5.51	2.05	0.504	330	4.94	1.84	1.007	610	5.39	2.71	1.027
3/8	3350	1090	5.27	2.35	0.463	440	5.30	1.99	1.181	590	5.38	2.88	0.822
1/4	3350	1270	5.06	2.77	0.328	820	5.04	2.37	0.454	880	5.10	3.49	0.580
3/4	3350	1465	5.05	2.68	0.307	1095	5.03	2.88	0.459	1150	5.30	3.75	0.437

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one make is equipped for this, although I cannot say as to how satisfactory this is going to be, as we have had practically no experience with it as yet.

There are many important factors in design which we have as yet been unable to study. Up to the present time we have been concerned chiefly in developing the mill to the point where it would feed uniformly at the desired rate, grind satisfactorily, not clog up, and dispose of the ground feed as fast as ground. This has been accomplished, and a few of the more important factors have been studied and will be reported upon.

We believe the hammer type feed mill, due to its inherent principles of operation, has important advantages over burr mills for automatic electric operation as follows:

1. They are not damaged, and do not use much power when running empty.
2. Foreign material going through the mill is not apt to do much damage to the mill, or to the animal which may take it in later. Nails, for example, are chewed up into more or less round pellets which certainly are not as likely to pierce the intestines as the sharp needle-like pieces that sometimes come out of a burr mill.
3. The mills maintain their original efficiency over long periods of time.
4. The high speeds adapt them readily to the electric motor.
5. They are proving to be very durable. For example, a large dairy farm near Waukesha, Wisconsin, is doing all the grain grinding with one of these mills, for some 240 head of milk cows, some young stock and horses. The first one, a belted machine, was used about one year and then exchanged for a direct-connected job. The latter one has been in service about 1½ years. They report no expenditure for repairs to date, and the present mill is in excellent condition. The first mill showed considerable hammer wear due to improper hardening. This demonstrates conclusively that the argument against the mill due to its small size and capacity is not well founded.

Equipment and Procedure for Tests. The equipment consisted of a 5-hp. electric cradle dynamometer, equipped with an electrically operated revolution counter, a magnetically operated stop watch for timing the duration of the experiment, and electrically operated signal bell, all manipulated through a master switch arrangement.

The belt used in all the tests, except those where two belts were required, was a 3-ply, 4-inch, endless rubber belt about 14 feet long, or 7 feet between centers.

The modulus determination was made according to the recommended standard as follows:

Size of Sample: 250 grams, dried to constant weight before weighing.

Moisture: Dry to constant weight at 100 degrees Centigrade before shaking.

Method of Shaking: Ro-Tap shaker.

Time of Shaking: Five minutes

Screens: Tyler standard screen scale sieves, Nos. 3½-inch, 4, 8, 14, 28, 48, 100-bottom.

Modulus: Prof. Duff A. Abrams' formula.

The testing work was all done at one of the University farms where ample facilities were available for supplying corn and oats, and taking care of the ground feed. The mills were operated with a blower pipe about 24 feet high, and about 14 feet across to a dust collector. The cross

pipe sloped downward to the dust collector at an angle of 30 degrees with the horizontal.

The dust collector was equipped with a bagging attachment which was rebuilt so as to be tight. One spout of the bagging attachment discharged into a box on a pair of scales. The other side discharged into a bin.

The procedure in making a test consisted of switching the bagger to discharge into the bin. The mill was started and operated for several minutes during the process of adjusting the rate of feed, until approximately a 5-hp. load was reached. When the mill had reached uniform operating conditions, and was using 5 hp., the test was begun and the bagger valve switched over so as to discharge ground feed into the weighing box. At the conclusion of the test, which in most cases was for a period of 6 minutes, the bagger valve was switched over to throw the ground feed over into the bin.

Thus the procedure consisted of taking a sharply defined test out of the middle of a run, thus eliminating variables while the mill is being started and stopped.

Considerable care was taken to keep the belt at a uniform tension and tight enough so as to avoid undue slippage, although excessive tension was avoided.

The pulleys on the grinders were all pressed paper pulleys. The pulleys on the motor were all pressed paper, except for the Rowell No. 1, in which case a 14-inch split steel pulley was used on the motor, the motor being a 1200-r.p.m. machine. The grinder speeds are all a trifle lower than would be secured with a modern single-phase motor. The dynamometer motor is rated at 1200 r.p.m. but drops to about 1120 r.p.m. under a 5-hp. load.

RESULTS OF THE TESTS

The Feeding Mechanism. The feeding mechanism above all things must be non-clogging and uniform in its rate of feed. An agitator is almost necessary. This can be operated at a very slow speed, 300 to 400 r.p.m. being ample, and not only can, but should be, very simple and produce a very small amount of agitation. A very satisfactory agitator consists of two short paddles about ¾ to 1 inch long, mounted on opposite sides of the agitator shaft, with one on one end and one on the other. The paddle should lie approximately in a plane at right angles to the shaft. In other words, it should be designed somewhat similar to the paddles on a windmill wheel. This construction uses a minimum of power and produces motion across the slide opening as well as stirring action. The agitator paddles should run close to the slide opening.

It has been found that a feed opening about 3 inches wide works very satisfactorily for a 5-hp. mill, and sufficient slide movement should be secured to obtain the desired capacity. This will probably not exceed 1 or 1½ inches under ordinary conditions. A wider throat does not permit of sufficient slide opening for light feeding.

The feed opening should be designed so that it will feed oats and barley uniformly at the rate of about 300 pounds per hour, and the adjustment of the slide should be such that increments of about 50 to 100 pounds per hour are secured, up to 700 or 800 pounds per hour capacity, and above this increments of 100 to 200 pounds per hour are satisfactory.

The bottom of the supply hopper should slope to the feed opening at an angle of at least 22 degrees. A sloping slide is desirable.

The Point of Feed. Experience indicates that mills which have the intake on the periphery should be so designed that the point of intake is almost directly above the shaft of the rotor, or later. Referring to the direction of rotation, if you look at the mill so that it is turning in a clockwise direction, the intake should be between the numbers indicating 12 and 2 o'clock.

Tests were conducted on the Prater mill with different percentages of the screen on the intake end covered. This reduced the overall efficiency, although it produced a little finer and somewhat more uniform product. This experience with the Prater mill would indicate that it might be advisable to have the feed intake as near the screen as possible, although we have no data applying directly to the type of mill with the intake on the periphery.

Correct Speed. The correct speed of a hammer mill is apparently a matter of prime importance, and the investigations which we have conducted along this line tend to indicate that the peripheral velocity is the important factor, which would seem to be a logical conclusion.

Most of the tests conducted to show the relation between speed and efficiency have been conducted on oats, as it is our experience that oats is the hardest of the ordinary farm grains to grind. It is possible that the most efficient speed for oats is not the most efficient speed for other grains, particularly shelled corn, but in

view of the fact that oats ordinarily takes more power than the other grains, it would seem best to speed the mill for the most efficient results on oats.

The Rowell No. 1 "Whip-it," with the old-style fan was operated at speeds of approximately 2300, 2800, 3400 and 3950 r.p.m. The results shown in Fig. 1 indicate that the higher speed of 3950 r.p.m. is most efficient for grinding oats.

The new Rowell mill, which is equipped with a slightly different type of fan, has not been checked up, but in view of the fact that the idle horsepower at 3400 and 3950 r.p.m. is practically the same for both the old and the new-style mills, we would conclude that the grinding results would also be approximately the same. To be exact, the mill with the new fan required 0.02-hp. more when running idle at 3950 r.p.m.

Fig. 2 shows the results of a series of tests on the Algoma "O.K." mill. In this case the speed of approximately 3400 r.p.m. gives best results on oats.

Some tests conducted on the Prater mill, grinding shelled corn, showed that a speed of 3400 r.p.m. was considerably more efficient than 3950 r.p.m.

The peripheral velocity of the Rowell mill at 3950 r.p.m. is 12,600 feet per minute, and on the Algoma "O.K." at 3400 r.p.m., it is 14,100 feet per minute. This would indicate that a peripheral velocity of around 13,000 to 14,000 feet per minute is optimum for this type of mill when grinding oats.

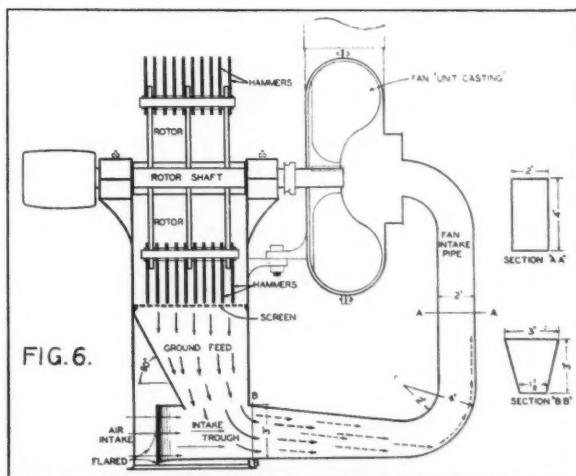
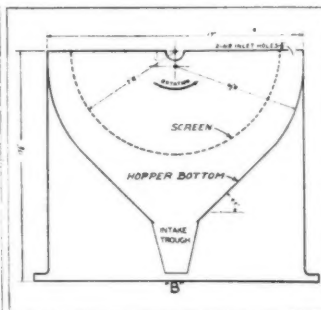
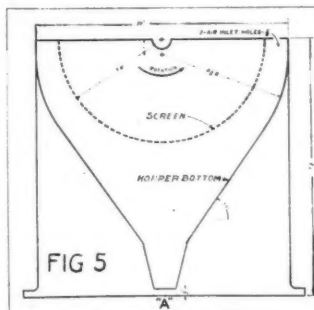
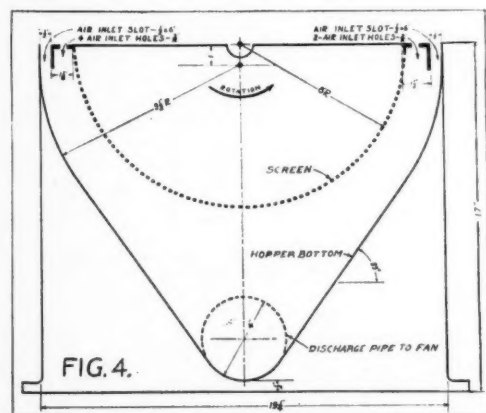
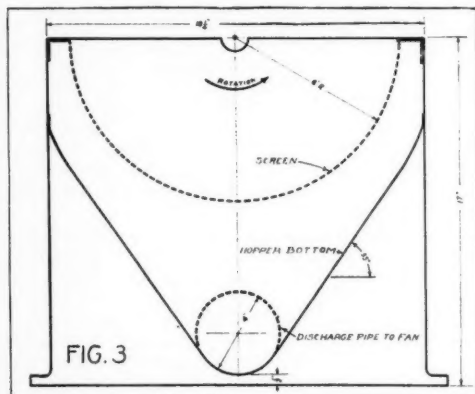


Fig. 3. This hopper bottom design clogged badly between the screen and hopper bottom, in some cases amounting to about 75 per cent of the entire screen area. All the air supplied to the fan must pass through the screen

Fig. 4. This is the result of redesigning the mill shown in Fig. 3. The air intakes are located so that the incoming air will sweep the bottom clean. The increased air supply for the fan increased its capacity about 50 per cent at 3400 r.p.m.

Fig. 5. The design "B" operated fairly satisfactorily. The principal air intake for the fan is at the bottom (see Fig. 6). The ground feed drops and slides almost entirely by gravity. Ample space between the screen and hopper bottom, together with smooth curves, are essential. The design shown in "A" is suggested as being preferable

Fig. 6. This is a view of the mill, the hopper bottom design of which is shown in Fig. 5

Size of screen opening, inch.	Speed of mill, r.p.m.	Corn				Oats				Barley			
		Pounds per hour	Arg. mod. 100 lb.	Fin. mod. 100 lb.	Sp. mod. 100 lb.	Pounds per hour	Arg. mod. 100 lb.	Fin. mod. 100 lb.	Sp. mod. 100 lb.	Pounds per hour	Arg. mod. 100 lb.	Fin. mod. 100 lb.	Sp. mod. 100 lb.
3/32	3950	580	5.18	1.43	1.015	300	4.94	1.96	1.645	325	5.88	2.00	1.630
1/8	3950	550	5.13	1.36	0.993	425	4.98	2.19	1.385	350	6.15	2.16	1.475
3/16	3950	525	5.33	1.27	0.950	445	4.91	2.68	0.787	380	5.16	2.77	0.800
1/4	3950	1045	5.07	2.54	0.485	800	4.88	2.78	0.548	770	6.30	2.82	0.674
5/16	3950	1580	5.18	2.58	0.409	1090	5.09	2.85	0.487	980	6.32	3.14	0.559

NOTE 1:

Test Results

Moisture

Corns 51 lb. per bu.

Oats 34 " "

Barley 45 " "

Moisture determination was by the Brown-Sherell method.

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Experience indicates that speeds of 4000 r.p.m., or even 4500 r.p.m., are practical for these small mills, when they are correctly designed. One of these small mills operating at 4500 r.p.m. has been under observation for about four years, and is still giving good service, and there have been no repairs to date to our knowledge.

It is worthy of note at this point that many large-size hamme' mills operate at even higher peripheral velocities than those shown here.

It can be observed, by referring to the curves in Figs. 1 and 2, that with the larger screens the quantity per unit of power remains practically the same as the speed increases, but the material is finer with increased speeds, while with the smaller screens, the modulus remains about the same but the amount of power required to grind a given quantity is less for the higher speeds.

Design of Fans and Fan Speeds. The fan is usually on the same shaft with the grinder rotor and its speed cannot readily be different than that of the rotor.

The fans on the small mills which we have worked with are all approximately of the same design at the present time. They are approximately 12 inches in diameter, 4 inches wide, with six fan blades which are practically radial. They are built with the housing concentric with the fan, and have approximately 1/8-inch plus or minus clearance. We have tried fans with both square and round tips, and both will function with approximately the same efficiency.

Some of the fans are built up. That is, the fan wings are riveted to a spider and hub. In others the fan is a unit casting, either cast steel or malleable iron. The unit casting seems desirable in view of the fact that we have heard some complaints of fan wing rivets becoming loose.

Hopper Bottom Design. The design of the hopper bottom underneath the screen which catches the ground feed and delivers it to the intake pipe to the fan, has been one of the most troublesome features of these small mills. The common trouble is that they do not clean properly, particularly with oats. The fine flour produced from the kernel of the oats sticks in the hopper bottom, gradually fills up the space between the hopper and the screen, and in some of the first designs we have found this to be so serious that as much as 50 to 75 per cent of the entire area of the screen was clogged after runs of from 5 to 10 minutes. This naturally decreases the efficiency of the machine tremendously. Figs. 3 and 4 illustrates the original design and the improved design of one of the machines which gave the most serious trouble. The hammers in this mill are 1/2 inch wide, and, apparently due to this reason, the mill either produces more flour with the same size screen than do other mills, or it is thrown through the screen with greater force. As a result, we have found that designs which would work in other mills do not work in this mill. The design, Fig. 4, cleans very satisfactorily.

The important items in the design of the hopper bottom appear to be as follows:

1. Ample clearance, particularly at the ends of the screen. This varies with different machines, and we have no definite formula worked out.

2. A slope of the hopper bottom of 60 degrees is preferred, although 50 degrees sometimes works successfully, particularly if air is taken in along the hopper bottom

Hammer	Alcona "OK"	Prater	Remell "Whipit"
Size of mill	6	5-7	1
Horsepower recommended	5 to 7 1/2	5 to 7 1/2	5 to 7 1/2
Screen	15 5/8	8 1/2 to 15	15 1/2
Width, in.	6 1/8	17	6
Thickness, in.	1/8	1/8	1/8
Hammer	8	51	16
Arrangement	4 rows	3 rows	4 rows
Size, in.*	1/2 by 2	1/8 by 1 1/2	1 by 2
Support	Rectangular	Rectangular	T-shaped
Rotor tip diameter, in.	Swinging	Swinging	Swinging
Feeder	14 7/8	7 3/4 to 17 1/2	12 3/4
Automatic	Yes	Yes	Yes
How regulated	Screw and slide	Screw and slide	Screw and slide
Agitator used	Yes	No	Yes
Drive	On grinder shaft	Belt	On grinder shaft
Diameter, in.	12	12	12
Width, in.	4	4	4
Housing clearance, in.	1/8	1/8	1/8
Fan blade construction	Built up	Built up	Unit casting
Blower pipe size, in.	4	4	4
Bearings	Ball	Ball	Ball
Pulley	Diameter, in.	4	4
Width, in.	6 3/4	4 1/2	4 1/2
Pipe size into fan, in. (diameter)	4	5 3/4	4

*Cross-section at end.

to keep it swept clean. (It might be noted here that oats is the most difficult material to handle.)

3. Smooth curves with a gradually increasing clearance between the screen and the hopper bottom appear to be desirable. (See Fig. 4.)

4. Ample and properly designed air intake is essential. The intake must be of ample size to avoid starving the fan. According to all our experience, there must be some air taken in below the screen. If all the air intake is through the screen, the capacity of the fan is usually limited when the mill is being fed heavily, due to the fact that a large portion of the screen is filled up with material. Air intakes located as shown in Fig. 4, where the incoming air sweeps along the hopper bottom, aid in cleaning. However, this type of intake is not so desirable when grinding shelled corn due to the fact that a few particles bounce out through these air intakes. This, however, can be overcome by proper shielding. In this connection the design shown in Fig. 5 is to be preferred, although greater difficulty is apt to be encountered with clogging under the screen.

The Goose Neck. The goose neck from the hopper bottom to the fan is usually made up of round, sectional elbows, the numerous joints of which obviously tend to slow down the movement of the material and reduce the capacity of the fan. An elbow of rectangular or square cross-section will give quite a little greater capacity if properly designed. The curves should not be less than those shown in Fig. 6, in which case the inside radius equals the width of the cross-section. This type of goose neck is more efficient, not only due to the square or rectangular cross-section, but also to the fact that smoother curves can be readily secured.

Fan Capacity. The fan and goose neck capacity should be somewhat greater than the capacity of the mill. However, too great a fan capacity will probably mean greater fan horsepower and this means lowered mill efficiency. We have found that with any particular fan and fan intake, the capacity increases very much more rapidly than

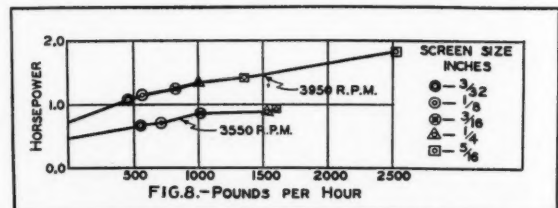


Fig. 8. The power required to operate the fan is comparatively small. The total power increases with the speed and rate of feeding. The amount of power per 100 pounds of feed ground decreases very rapidly as the rate of feeding increases. The tests were run on corn and the rate of grinding for each screen was approximately such as to equal a 5-hp. load for the entire mill, except the last point to the right on the upper curve. The last two points on each curve represent maximum capacity for the particular speed

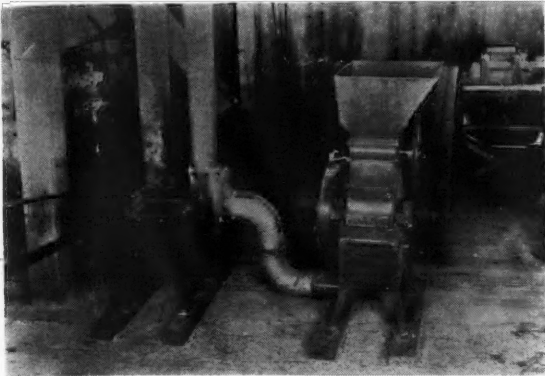


Fig. 9. This shows the arrangement used to determine the power requirements of the fan. The mill was operated by a regular 5 hp. motor and the fan by a dynamometer motor

the speed increases. Fig. 7 shows this graphically. The fan reported in Fig. 6 has been superseded by a later design. The old-style fan used in this test had a clearance at the tips and sides of $\frac{1}{2}$ inch plus or minus. The new fan which has a fan housing that is rectangular in section, and fan wings that fit within about $\frac{1}{4}$ inch of the fan housing, had a maximum capacity of 2530 pounds of corn per hour at 3950 r.p.m., and 1600 pounds per hour at 3550 r.p.m., so that apparently the same general relation between speed and capacity as shown in Fig. 6 holds in the new fan.

Fan Horsepower. The fan horsepower is a matter of considerable importance and the entire fan and elevating mechanism should be carefully designed so as to keep the fan horsepower as low as possible. Fig. 8 shows the method used in determining the horsepower required to operate the fan where the fan is on the same shaft as the rotor. The net fan horsepower was secured by determining and subtracting the belt, shaft and bearing load from the total load.

Tests were conducted on each of the various screens with the capacity for each screen kept as nearly as possible equal to a 5-hp. load for that particular screen. This apparently was an unnecessary precaution. Results were as follows: The horsepower increases with increased capacity and increased speed. At 3550 r.p.m., the power varied from 0.67 hp. for 560 pounds per hour to 0.93 hp. at 1600 pounds per hour, and at 3950 r.p.m., the power varied from 1.09 hp. for 475 pounds per hour to 1.85 hp. at 2530 pounds per hour. The idle power at 3550

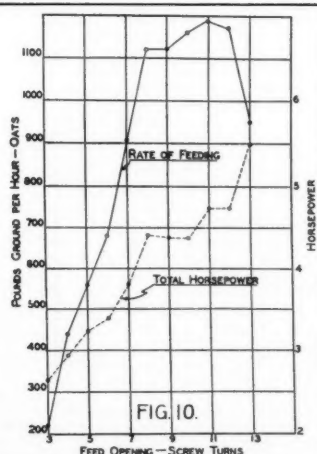
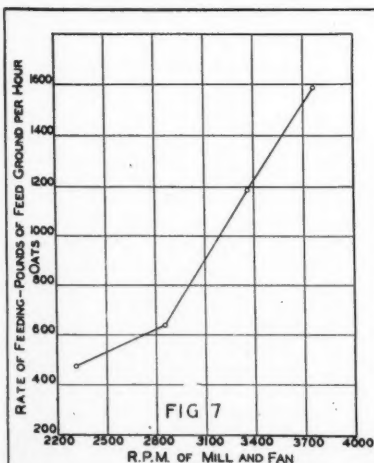


Fig. 7. This curve shows the relation between the speed of the fan and its maximum elevating capacity. The fan is located on the rotor shaft, and the ground feed is drawn by suction from the bottom of the mill up into the fan. Failure to elevate in this type of construction occurs in the suction pipe

Fig. 10. These curves show the relationship between the feed gate opening, the rate of feeding and the total horsepower. The efficiency increased rapidly up to about 1190 pounds per hour; beyond this point it dropped off rapidly due to overloading. The efficiency peak will be different for different speeds, grains and screens

Table V. Results of Tests Comparing 4 Rows and 8 Rows of "T" Hammers			
Rotor diameter, 12 3/4 inches clearance, 3/8 inch		Hammer and screen Material, oats	
Screen, 3/32 inch	Eight rows of hammers	Four rows of hammers	
Average F.p.m.	3518	3518	
Pounds per hour	156	132	
Average kilowatts	4.46	4.08	
Kw-hr. per 100 lb.	2.87	3.09	
Fineness modulus	1.88	1.85	
Screen, 1/4 inch	Eight rows of hammers	Four rows of hammers	
Average F.p.m.	3518	3518	
Pounds per hour	766	803	
Average kilowatts	4.06	4.25	
Kw-hr. per 100 lb.	0.519	0.482	
Fineness modulus	2.95	2.89	

NOTE: These data was secured with a 5-hp., 1800-r.p.m., single-phase motor and a watt-hour meter. The power data represents total energy input. The results would indicate that 4 rows of hammers are better than 8 rows.

Table VI. Results of Tests to Show Effect of Worn Hammers and Worn Screens						
Rotor diameter, 12 3/4 inches clearance, 3/8 inch			Hammer and screen Material, oats			
Mill r.p.m.	Screen	Hammer "T"	Pounds per hour	Average hp.	Fineness modulus	Hp-hrs. per 100 lb.
3400	Old	Old	1182	3.83	3.803	0.324
3400	Old	New	954	4.56	3.013	0.480
3400	New	New	1183	4.77	3.030	0.403
3400	New	Old	1080	4.03	3.256	0.373

NOTE: The machine had ground a little over 1200 bushels of corn and 2000 bushels of oats before these tests were made.

r.p.m. was 0.46 hp., and at 3950 r.p.m., 0.73 hp. Where the fan is located below the rotor and driven by means of a belt, a little more power is required at the same speed of the fan.

Types and Arrangement of Hammers. We have very little data or information relative to the merits of different styles and types of hammers, including the number, arrangement, and shape.

Table V shows the results of using four rows and eight rows of "T" hammers. The conclusions from this would be that four rows are to be preferred.

Table VI shows the results of wear on a hammer mill. The particular mill used had ground a little over 1200 bushels of corn and 2000 bushels of oats when these tests were conducted, and practically all the grinding had been done on the particular screen used in making these tests. This shows that a screen that is slightly worn grinds finer than a new screen, but with about the same efficiency as a new screen, and that worn hammers grind coarser than sharp hammers and with reduced efficiency, showing the importance of properly hardening the hammers.

Screens. There is apparently some difference in the

performance of thick and thin screens, although we have no definite information on the subject. Substantial construction is a matter that must be taken into consideration in connection with this, as well as the thickness of the screen. As pointed out before, screens that are slightly worn apparently grind finer than new screens, but if the wear becomes excessive, the opposite would probably be the case. However, the screens can be turned end for end and then can be rerolled, thus bringing the outside of the screen to the inside.

We have but very little data relative to the relation between screen area, mill capacity, and horsepower. Such as we have is shown in Fig. 8. In this particular instance the screen is 6 inches wide and 13½ inches inside diameter. When using a ¼-inch screen grinding oats, the mill will efficiently use just a little under 5 hp. When the capacity is increased beyond this point, the actual pounds per hour decrease and the efficiency decreases. However, increasing the speed of this mill increases the peak load beyond 5 hp. It is also likely that the mill would peak at different points for different screens and different grains, and these matters should be given rather careful attention in the design of the mill, and a compromise will probably have to be arrived at bearing in mind that oats is probably the hardest material to grind.

Elevating Grain. The practical use of these small mills involves overhead storage of grain, and this has been more or less of a stumbling block in the way of their adoption, in view of the lack of elevators on Wisconsin farms. We felt that we could not justify the purchase of an elevator on the average Wisconsin farm. However, it has developed that the fan on these small mills can be used very successfully for elevating grain into overhead bins. We do not consider them particularly successful for moving the grain long distances through horizontal pipes, as excessive speeds will be required and this would damage the grain, which with these mills goes through the fan. Where the fan is on the same shaft with the rotor, the usual practice is to remove the goose neck and attach a special hopper which feeds the grain directly into the fan. Where the fan is below the rotor, the usual practice is to belt directly to the fan, leaving the rotor stand idle; remove the screen; and use the same hopper as when grinding. Thus the grain falls over the stationary rotor directly into the fan and is elevated. Capacities of 250 to 500 bushels per hour are readily secured when elevating oats to heights of from 15 to 38 feet.

The points to be observed in the design of the fan for this work are, first, that the fan housing be concentric with the fan, with clearances of ⅓ inch plus or minus. Second, an ample air intake must be provided along with the grain. Third, a speed of 1800 r.p.m. will elevate oats and presumably other grains, to heights of 15 to 25 feet, and a speed of approximately 2500 r.p.m. will elevate oats 38 feet, although some hulling will result at this speed. No perceptible hulling or cracking is produced on oats at 1800 r.p.m., although we do not recommend elevating seed grain by this method until further tests are made to determine whether germination is damaged.

Small Mill Installation. Any discussion of small mills is not complete without a brief discussion of installations as this determines in the end whether or not the proposition will be successful and satisfactory.

If possible the entire supply of feed grain should be stored in bins over the mill at threshing time. If these bins and the mill are properly located with reference to the feeding alleys, no further handling of the grain will be necessary until it is put into the feed cart or onto a mixing floor.

Grain bins with flat floors are recommended. They are usually emptied but once a year, and the expense and waste space of hopper bottoms does not seem warranted.

Ground feed bins should have hopper bottoms with slopes of 45 degrees or more for corn and barley, and at least 60 degrees for oats. Even with this slope a



Fig. 11. This shows the method of using the fan of a small hammer type feed mill for elevating grain. Run the fan at 1500 to 2000 r.p.m. Have the blower pipe straight and vertical. When the grain is very dry, there will be a small amount of hulling or cracking if the fan is run faster than 1800 to 2000 r.p.m., whereas grain directly from the threshing machine, which is usually slightly tough, will not be damaged appreciably by the higher speeds. These fans will elevate 250 to 500 bushels per hour

simple agitator will probably be needed in the ground oats bin.

Chutes 6 inches square or round are satisfactory for grain and should slope at an angle of at least 25 or 30 degrees. Ground feed chutes should be 10 to 12 inches square or round and should be as nearly vertical as possible.

Proper Belts Essential. A belt of the usual farm variety will commonly spell failure on a small hammer mill. The common farm belt is too thick and stiff for the small, high-speed grinder pulley. A 3-ply, rubber belt, 4 inches wide, gives excellent results. An endless belt is decidedly better than a laced belt. Waterproof light or medium weight single-ply leather belting also works very satisfactorily. This can readily be glued up endless. Pulley centers of 5 to 8 feet are good.

AUTHOR'S NOTE: Credit for assistance in this work is due J. P. Schaefer, rural electrification project leader, and the following students who helped in conducting the tests and in preparing the report: L. J. Heywood, H. A. Inman, V. L. Stroebe, R. A. Templin and H. F. Wisch.

Seeding Rice with Airplanes

Editor AGRICULTURAL ENGINEERING:

WITH reference to my article, entitled "California Rice Land Seeded by Airplane," appearing on page 69 of the February 1930 number of AGRICULTURAL ENGINEERING, I notice that the company which did the seeding of the section of land for the Crocker-Huffman Land & Water Company is advertising that they will seed land this year at the rate of \$1.00 an acre, and they claim to be able to save about fifteen pounds of rice per acre due to getting the same stand of rice with the smaller amount of seed when the rice is sown in the water. Rice is worth approximately 2 cents a pound, which makes a saving of 30 cents an acre, which apparently reduces the net cost of airplane seeding to about 70 cents per acre.

This seems to be quite reasonable and because of the numerous advantages may attract quite a number of the larger ranchers to the method.

E. N. BATES.

In charge, Pacific Coast Grain and Rice Investigations, U. S. Department of Agriculture

The Hill Planting of Cotton and Checker Cultivation with Large Tillage Implements

By J. O. Ware¹

A SERIES of field experiments have been conducted by the Arkansas Agricultural Experiment Station looking toward the reduction to a minimum of the hand work in the production of cotton.

Ordinarily the crop is planted in drills, the cotton set to a stand with hand tools, and the weeds and grass taken out of the rows by hacking or chopping. In this experiment the cotton was planted in checkered fashion, or check rows, largely eliminating hand work to produce a stand, except when necessary to thin for experimental purposes. When this procedure is supplemented by cross cultivation with such tools as the weeder, rotary hoe, or spike-tooth harrow, it seems probable that, under many conditions, machine methods and larger power units may largely supplement hand methods for thinning the stand and removing weeds and grass.

Previous experiments² dealing with spacing plants in the row, have indicated that the cotton plant, when grown on good soil and when permitted to vegetate and fructify throughout the season unmolested by pests and weather hazards, has the ability to adjust itself to about the same acreage production within a wide range of distances apart in the row.

The row spacing trials embraced 38 tests conducted over a five-year period (1922-26, inclusive). Each test included 12 plots with the rate of stand as the variable. The plot with the thinnest stand contained 6945 plants to the acre (approximately one plant every two feet in a four-foot row), and the plot with the thickest stand had an acre rate of 72,213 plants (unthinned four-foot rows). The stand in the other ten plots increased by somewhat regular increments from the lowest rate to the highest. With such a wide range in stand a large difference in production was expected, but when the 38 twelve-plot tests over the five-year period were averaged for the respective stand rates, remarkably little difference in yield occurred between any of the spacings.

There was a difference in acre yield of only 10 pounds between the thinnest stand and the thickest stand. The largest difference between any of the twelve rates of stand was only 79 pounds. The highest production ranged between 11,000 and 25,000 plants an acre, with yields tapering to slightly less as the extremes in stand are approached. It should be borne in mind, however, that the tests were located on land above the average in fertility and that,

when boll weevils appeared, calcium arsenate was used. The same results from poor land or from crops badly damaged by disease and insect pests may not universally obtain.

There was a greater difference in the first picking yields than with total production. Thicker stands tend to speed up fruiting, and the wide spacings were inclined to be later. The thinnest stand plot produced an acre yield of 196 pounds less than the highest yielding plot at the first picking. The higher first pickings ranged between acre stands of 15,000 plants to 50,000 plants. The unthinned plot with an acre rate of 72,213 plants scarcely showed any reduction in the first picking yields. Material reductions in the first picking were shown with the thinnest spacing, 6,945 plants to the acre. Falling off in the first picking yield was appreciable up to 10,000 plants.

In thinner stands the lateral branches are required to produce a larger percentage of the crop. The "limb" crop is later in setting fruit and consequently matures at a period further in the season. Thick spacing under the conditions of these experiments is chiefly a boll weevil measure.

Hill Planting. As the drill-spacing trials, conducted in the situation heretofore described, revealed the fact that cotton production was little affected by a wide range in stand, the spacing experiments were revised and changed in 1929 to a system of planting in hills 3 by 3 feet apart, and cultivating at right angles. The plan of the test included 10 plots. The object of the revision was (1) to determine whether the same acre stand grouped in hills would display similar effects on earliness and final production as when distributed in the row; (2) to determine the most practical number of plants to grow to the hill; and (3) to adopt the best cultural methods to avoid hand labor.

The stand variable through the ten plot series was from one plant in the hill to an unthinned clump. The number of plants to the hill in the respective plots are shown in the second column of the accompanying table. The test was planted in four series at the Cotton Branch Experiment Station in Lee County and in ten series at the Scott Experimental Field near Little Rock. At the former location, the land upon which the tests were grown is similar to that on which eight of the drill tests were conducted, and at the latter location the land is the same that had grown thirty of the drill tests.

As with the drill tests, the results are averaged and converted to an acre basis. The tests of the two localities, fourteen in all, are compiled in the table. The plots are



These pictures show cotton planting operations with four-row planter (a hill dropping machine) on the plantation of Conway Scott (the gentleman at the extreme right of the picture facing the camera) in Pulaski County, Arkansas. Mr. Scott had a solid block of 100 acres of cotton put in last year following the hill planting and checker cultivation method described by Mr. Ware in the accompanying article

¹Associate agronomist, Arkansas Agricultural Experiment Station.

²Cotton Spacing (Studies of the Effect on Yield and Earliness) Arkansas Agricultural Experiment Station Bulletin 230.

Results of Hill Planting and Checker Cultivation Experiments With Cotton (Average of fourteen tests calculated to an acre basis)							
Plot No.	Plants to the hill	Actual stand, no. plants	Theoretical stand, no. plants	First picking, pounds	Gain or loss	Mean of three rows, pounds	Gain or loss
2	1	4710	4840	571	-504	1378	-63
3	2	9024	9680	711	-64	1513	-72
4	4	16340	19360	815	-40	1499	-68
1 ck	5	20236	24200	830	-65	1503	-62
5 ck	5	20289	24200	758	-17	1459	-18
6	6	23701	29040	846	-471	1530	-479
7	9	31203	43560	802	-427	1422	-19
9	12	37548	50880	791	-416	1362	-79
10	15	40640	72600	848	-473	1423	-18
8	Unthinned Average	54550	-	779	-44	1334	-107
				775		1441	

arranged in the table according to the ascending order of the stand. This is not the order in which they occurred in the field. The first column at the left of the table gives the plot numbers. These numbers indicate the order of field arrangement of the plots. Last spring was a rather difficult season in which to obtain a good stand. The extended cool weather was severe both on the germinating seedlings and the plantlets after they had appeared above ground. The weather condition resulted in a failure to get the intended number of plants in all the hills, especially those of higher numbers. The actual numbers that grew to maturity were counted. The numbers obtained are reported in the third column of the table opposite the fourth column which contains the numbers for a perfect stand. When planning the tests, it was thought that five plants to the hill would result in the most desirable stand. This number was taken for the check plots as standards of comparison. The first plot and the sixth in each series was thinned to five plants. It was impractical to use drill plots for standards or controls as such plots interspersed at intervals would interfere with cross cultivation.

The results obtained at each locality showed more irregularity in yield than was indicated in the summary of the 38 drill tests, but this is to be expected since there were only four series at the Cotton Branch Station and only ten series at the Scott Experimental Field. Probably after the hill planting tests are run a sufficient length of time to get 38 tests, they too will show just as much regularity.

In the table, where the 14 tests are averaged, fluctuations are considerably balanced and the same tendencies are seen in the hill planting as obtain in the drill planting:

1. The extremely thin stands and the extremely thick stands reduce the total production somewhat.
2. The first picking is reduced much more by a thin acre stand than is total production.
3. The thick stand does not reduce the first picking as much as it does total production.
4. The highest total yields fall within about the same range of acreage stand in both systems.
5. The range of higher first picking yields is further in the direction of thicker stands of the hill planting than is the range of best total production, which is also the case as found in the drill spacing results.

The total production at the Cotton Branch Station was somewhat lower than the average of the 38 row tests, while the total production at the Scott Experiment Field was higher, but the average of the 14 tests from the two places coincides very closely with the drill spacings. The total average production of the 14 hill planting tests was 1441 pounds of seed cotton. The average yield of the 38 row tests was 1431 pounds. Nearly all the 1929 work was conducted on the same land upon which the drill spacing tests previously grew. The current year as a favorable cotton season, no doubt, was below the average of the seasons of the five-year period, 1922 to 1926.

CONCLUSIONS

1. On bottom land, or on other land of a high degree of fertility, cotton seems to produce as well when the



A weeder-harrow was used in the Arkansas field experiments in going across rows of young cotton. This implement was used in some of the cotton-spacing experiments, in which the use of the hoe for either thinning the stand or removing weeds and grass, was practically eliminated. A few scattering bunches of crab grass and Johnson grass, which the cultivators failed to destroy, were hacked out with a hoe in midseason at a cost of approximately 75 cents an acre

plants are grouped in hills arranged for cross cultivation as when the plants are distributed in rows.

2. Thickness of planting in hills appears to accomplish the same result in stimulating earliness as has been shown for close spacing in the drill.

3. No exact number of plants to the hills seem necessary. According to results, the number can range from two to six plants per hill or around 10,000 to 25,000 an acre. However, since the production was lowered less with 15 plants to the hill than with one plant to the hill, the stand maintained should be nearer the upper limits of the range of highest yields rather than toward the lower side of this range.

4. Hill planting, cross harrowing, and checkered tillage practically eliminates the hoe as a weapon for killing grass and weeds, and renders hand thinning unnecessary, except in an occasional hill where the plants are too numerous.

5. The release of much hand labor from the acreage of cotton customarily cultivated will afford more time to till an increased area.

6. The system of hill planting lends itself to easier adaptation of implements with larger tillage capacity and a larger cultivated area per farmer will necessitate the utilization of more power units per man.

RECOMMENDATIONS

A sufficient quantity of sound seed should be planted to give a stand somewhat beyond the upper limits of best production. The failure of a few seed to germinate, the dying of a few plantlets, and some further reduction in stand brought about by cross harrowing will, all agencies working together, lower the stand rate to some point within the limit of best yields.

A two or four-row hill dropping planter should be used, depending on whether a two or four-row cultivator is to be employed. If motorized cultivation is to be practiced the four-row machine is likely to be more economical.

A cross-harrowing just previous to the sprouting of the cotton seed and a second cross-harrowing at another angle immediately after the plantlets have straightened up from germination should prevent any noxious plants from developing in the hills amongst the cotton plants. As a further precaution against the occurrence of foul plants, an early cultivation with a double-gang, spring-tooth cultivator is essential. The inside tooth of each gang should have a twist so as to scoot fine dirt underneath the fender blades, thereby burying any tiny weed and grass seedlings that may be appearing around the young stalks. This operation should end the tedious work. The plants by this time should have a start at growing. Rather large implements can be used to keep weeds and grass under control and to finish the seasonal cultivation.

Supplemental Water for Irrigation¹

By Hugh A. Brown²

EARLY in the history of the Bureau of Reclamation of the U. S. Department of the Interior, it became apparent that it would be economically feasible to construct reservoirs adequate in size to store sufficient water to meet the needs of the federal project lands for which they were primarily to be used, and at the same time serve as regulating basins for the storage of surplus water for which a nearby market might readily be available at that time or potentially available in the course of future private development.

When construction of the North Platte federal irrigation project, in Nebraska and Wyoming, was authorized in 1904, the total irrigated area in the North Platte Valley was approximately 50,000 acres. It was evident that without storage and river control even this relatively small area could not be materially extended under irrigation. As a result the Pathfinder Reservoir, in Wyoming, was constructed to its full capacity, even though the federal project could not utilize the entire storage and there was no immediate market for the surplus. This decision received the enthusiastic support of the beet sugar interests, which entered into an active campaign for the extension of this industry in the valley during the succeeding years. The benefits of river regulation, through the construction of Pathfinder Reservoir, were so pronounced that the private canal companies west of Bridgeport requested the Secretary of the Interior to permit them to buy supplemental reservoir storage in the reservoir as an insurance against water shortage in the latter part of the irrigation season. This request was granted, and practically all these private companies between the Wyoming-Nebraska state line and Bridgeport availed themselves of the privilege and purchased supplemental water to the aggregate amount of 344,000 acre-feet at a cost of more than a million dollars. Last year water was furnished from the government works alone for the irrigation in whole or in part of 300,000 acres in this valley.

The Arrowrock Reservoir on the Boise federal irrigation project, Idaho, is another example of a reservoir

which, at relatively little additional cost, was constructed with a capacity considerably greater than at that time was considered necessary for the irrigation of the lands included in the project, but with the distinct idea in mind that the surplus storage would find a ready market sooner or later among the private organizations in the vicinity whose normal supply of water was inadequate for their needs. That this opinion was justified is evidenced by the fact that a number of these organizations, suffering from an inadequate supply, have gladly entered into contracts providing for the purchase of surplus water to the extent of 32,000 acre-feet, at a cost of \$528,000.

In general, contracts for the sale of surplus water provide for the purchase of a definite amount of storage capacity in a given reservoir at a specified cost per acre-foot, such cost to be returned in annual payments, without interest, over a period of years.

An entirely different method was used, however, in financing the construction of American Falls Dam on the Snake River, Idaho. The Snake River Valley is one of the largest irrigated valleys in the United States. It contains thousands of irrigated farms, with a total population of 250,000 people. Inadequate water supply for the various irrigation districts along the valley led to negotiations for the construction of a new reservoir at American Falls. A large part of the valley is under the American Falls Reservoir District No. 1. Under contracts with the federal government this district and other smaller districts, aggregating approximately 1,500,000 irrigable acres, advanced \$3,378,000 to finance the cost of the great reservoir at American Falls, with a capacity of 1,700,000 acre-feet, the total cost of which is about \$7,500,000. The additional water supply furnished the farmers throughout the valley is expected to increase the value of crops grown annually by approximately \$40,000,000 under full development.

An interesting table was compiled recently by the chief accountant of the Bureau of Reclamation. Since the passage of the Warren Act the Bureau has entered into 77 contracts for the sale of supplemental water for irrigation. These contracts have a total value of \$7,514,521 and involve the purchase of 1,600,000 acre-feet of water. The irrigated area of these lands served in whole or in part with water from the government works

¹Paper presented at a meeting of the Land Reclamation Division of the American Society of Agricultural Engineers, at Kansas City, Mo., December, 1929.

²Director of reclamation economics, Bureau of Reclamation, U. S. Department of the Interior.



Cleaning out an irrigation ditch with a tractor and scraper

amounted last year to 1,235,020 acres, of which 1,192,030 acres were cropped, producing crops valued at \$62,500,000. Repayments due under these contracts to June 30, 1929, amounted to \$5,333,519, of which all but \$72,190, or about 1.3 per cent of the amount due, has been paid. In the case of the American Falls development, as stated above, \$3,378,000 was contributed to the government in advance of construction. Although it is true that a few of these contracts have been modified to provide for a longer term of payment, as has been found necessary in the contracts with the water users' organizations on some of the federal projects, this is undoubtedly a remarkable record of repayments, involving as they do a range from a few hundred to two million dollars. Thirty-nine of these contracts are for the sale of surplus water from storages on the Minidoka project, Idaho, with only one in arrears; seventeen are under the Yakima project, Washington, with only one delinquent; ten are under the North Platte project, Nebraska-Wyoming, with three delinquent; six are under the Boise project, Idaho, with one delinquent; and four are under the Klamath project, of which three are in arrears.

Despite the excellent record of repayments taking the discussion as a whole a few of them are not in good financial condition, owing to causes with which the United States has been in no way connected. The responsibility for their success lies with the private organization so long as the United States carries out its part of the contract obligations. It is a question, however, whether the largest usefulness under the Warren Act would not be gained if the United States exercised the same caution in entering into Warren Act contracts as it now exercises in determining the feasibility of strictly federal projects. There is of course involved in this the desirability of protecting the government's investment. But aside from this, the fact that it is generally known to the public that a Warren Act project is being furnished water from a federal storage reservoir might well result in the purchase of such land by settlers chiefly because the government is a participating agency. During the past summer an economic survey of certain federal and private projects was made by the Bureau of Reclamation. Among the questions given consideration was that of the responsibility of the United States under Warren Act contracts. This report has recently been made available for public distribution. In the discussion of this question it was the general consensus of opinion that before a contract was entered into with a private organization for the purchase of surplus water under the Warren Act, such project should be subjected to the same tests of feasibility as are now required before a strictly federal project is recommended for construction².

The investigators also were of the opinion that construction by agencies seeking assistance under the Warren Act should be carried out under sufficient government supervision to insure a satisfactory standard of work; and that the financing of the project which is to receive such assistance should be satisfactory to the Secretary of the Interior.

If these checks and safeguards were insisted upon they would result in withholding aid to infeasible or premature projects, and, on the other hand, in the case of projects that can be successfully carried out if soundly planned and effectively supervised, the general reclamation program would be strengthened and federal aid would be

²"No new project or new division of a project shall be approved for construction or estimates submitted therefor by the Secretary until information in detail shall be secured by him concerning the water supply, the engineering features, the cost of construction, land prices, and the probable cost of development, and he shall have made a finding in writing, that it is feasible, that it is adaptable for actual settlement and farm homes and that it will probably return the cost thereof to the United States."

largely confined to communities which have a proper claim to it.

The preceding discussion has had to do with those instances in which the federal government, in connection with its primary purpose of furnishing an adequate water supply to strictly federal projects, has, as an incident thereto, furnished the whole or a supplemental supply to adjacent, private developments from available surplus storage.

Another phase of our work has to do with the construction of storage works primarily to meet the needs of already partially developed communities, whose water supply is inadequate to meet their needs. A typical example of this is the construction now being carried on by the Bureau in Utah, where the Echo Reservoir is being built to furnish an ample supply of water for the irrigation of about 80,000 acres of land in the Salt Lake Basin. All of this land is in private ownership, is fully colonized and settled, but needs a supplemental supply of water for late irrigation. The land embraced in the project is of more than average fertility, and can be utilized for the production of crops with the effective application of water. The farmers on the project have savings and checking accounts in the local banks, are industrious, pay their debts, and constitute a solid class of citizens in Utah.

A contract has been entered into with the Weber River Water Users' Association for repayment of the cost of the construction in twenty equal annual installments, payment to begin on December 1 of the year in which the Secretary of the Interior announces the completion of the expenditures for the first unit. The average construction cost of this division will probably be about \$40 an acre, making the average yearly payment \$2 an acre, to which will be added the annual expense of operation and maintenance. The total yearly charge, however, will not be greater than the irrigators can pay, and there is every reason to believe that the additional water supply will increase their incomes to such an extent that they will be able readily to meet the required payments.

A similar contract is in process of negotiation with the farmers in Cache Valley, Utah, for the construction by the bureau of Hyrum Reservoir, with a capacity of 20,000 acre-feet on the Little Bear River, and the enlargement and extension of present canals, for the purpose of supplying water to 26,000 acres, 4,000 of which are new lands and 22,000 acres lands in need of a supplemental supply. This second unit of the Salt Lake Basin project comprises lands situated in a well-settled community, having excellent transportation and markets and with good climate and crop conditions. The cost of the reservoir and appurtenant structures will approximate \$1,600,000 and will be repaid over a period varying from 20 to 40 years. The lands now under production will probably be required to repay their share of the cost in the shorter period.

There can be no question of the value of such work by the Bureau of Reclamation. The safety of the government's investment is assured, because the work is done not in a sparsely settled region where settlement and development must be built up over a long period of years before the construction cost can be announced and repayments commence, but in localities already settled as active growing communities, but handicapped in attaining their full development because of the lack of an adequate water supply usually for late irrigation, and their inability to finance the necessary construction. Such work is in direct line with President Hoover's suggestion in his letter of August 21 to Hon. Joseph M. Dixon, First Assistant Secretary of the Interior, that in the case of certain insufficiently capitalized community-owned irrigation projects the reclamation fund might be made a proper vehicle to rescue homes that are now in jeopardy.

Tests of a Commercial Sweet Potato Storage House¹

By M. A. R. Kelley²

THE successful storage of sweet potatoes depends upon the prevention of the development of rot-producing fungi which require heat and moisture for their growth. A knowledge of the physical conditions essential as they relate to the maintenance of proper conditions to good storage and the properties of heat and moisture particularly by means of ventilation, is necessary.

Potatoes are living, breathing organisms and when stored in bulk give off heat and moisture, at first rapidly and then more slowly until they become dormant. The surface of the potatoes should be kept dry. The excess heat and moisture are best dissipated by thorough ventilation.

The earliest type of storage was the kiln formed by piling the harvested stock on a bed of straw and covering it with earth. This method is still used by the small grower for preserving his supply for family use. In later practice sweet potatoes were cured and stored in bins, barrels, crates or hampers in insulated houses without artificial heat except when required to prevent chilling. Heavy losses occur in both types of storage owing to lack of control of air conditions.

Studies made by the U. S. Department of Agriculture show the loss by decay in potatoes stored in pits or banks was fully 30 per cent, and in many cases the loss was complete. In addition, potatoes stored in such manner were of poor quality and decayed rapidly after removal from storage. Tests made in good houses showed a range of shrinkage of 5 to 10 per cent under careful handling with an average of 7.5 per cent. Under average commercial handling the shrinkage varied from 7.4 to 20.4 with an average of 10 per cent.

Investigations of the Department of Agriculture led to the development of a storage house in which artificial heat and controlled ventilation are employed, making it possible to cure the stock at a high temperature and to maintain a uniform storage temperature throughout the storage period. The control of air conditions within the storage makes for greater assurance of good results.

The general principles of good storage have been fairly well determined, but owing to lack of understanding on the part of operators of the fundamentals of ventilation, the requirements of good storage, and the importance of maintaining proper conditions they have not been ob-

served in common practice. The test herein reported shows that it is possible to maintain the desired temperature in a well-insulated and ventilated house if it is properly operated. Ventilation with outside air is the only means of cooling the house and in removing the moisture, hence the storage conditions which can be maintained will depend upon the judicious operation of the ventilation system in accordance with weather conditions.

Purpose of Investigation. The investigation recorded in this paper was undertaken primarily to demonstrate the possibility of maintaining fairly uniform conditions in commercial storage houses and to obtain data upon which to base recommendations as to operation and possibly for improvement in the design of such storages. The complete report cannot be given here, but it will be made available as soon as possible.

Two storage houses of same construction were erected on the Del-Mar-Va peninsula in the section known as the Eastern Shore of Virginia, during 1926, one at Melfa and the other at Painter near by. Plans, based upon the best information available were prepared by the U.S.D.A. Division of Agricultural Engineering. During the first storage season two short-period tests of the heating and ventilating systems were made and during the storage season of 1927-28 a complete record of the entire storage period was obtained.

Description of Storage House. The building is 45 by 100 feet and consists of three floors with a total capacity of approximately 10,000 barrels. The first floor is used for the storage of white potato seed. The two upper floors, each divided into two rooms of approximately equal capacity, are used for the storage of sweet potatoes.

The walls are of 12-inch cinder block for the first floor and 8-inch block for the upper floors. Pilasters of the same material are used to stiffen the walls and support the heavy loads. Steel columns and girders support the wood floor and joists with wood posts and purlins support the roof.

The roof consists of 2x6-inch rafters carrying 1-inch matched sheathing, ½-inch of commercial insulated board, a second layer of 1-inch matched sheathing, and over this a heavy unsurfaced prepared roll roofing.

A centrally located electric elevator with a platform capable of holding 20 barrels, the usual full wagon load, is provided to facilitate handling the storage stock.

A ventilating system, together with a heating system, provides control of temperature and moisture within the building and constitutes a very important feature of potato storage design.

Outside air is introduced into the first story through windows and large driveway openings. These are fitted with sliding doors outside and folding hinged doors inside. It is very important that these doors be tightly closed so as to reduce the air leakage to a minimum. Owing to the presence and frequent use of the driveway, it was practically impossible to maintain the desired inside temperature on the first floor.

Air is admitted to the two upper stories through a number of small ports just below the floor line and so spaced as to obtain uniform distribution of air. These ports open into ducts extending along the side walls. Sectional hinged covers permit control of the entering air. It is essential that these doors be easily operated, otherwise their use is neglected resulting in faulty distribution of air within the house.

The primary purpose of the windows is to provide light for the workers within, but they are occasionally used as auxiliary air inlets. The windows are few in number

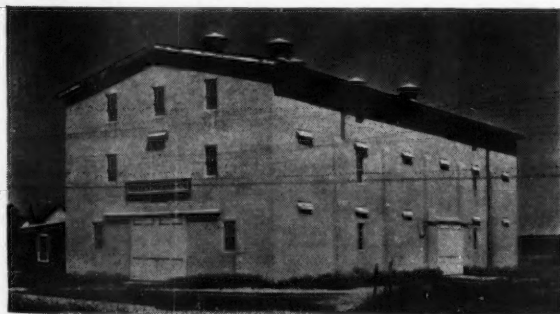


Fig. 1. One of the commercial storage houses erected at Melfa, Virginia, in connection with the sweet potato storage investigation conducted by the U.S.D.A. Division of Agricultural Engineering

so as to permit better control of temperature and are fitted with tightly closing shutters, preferably on the inside, so as to reduce condensation of moisture on the glass and minimize the loss of heat.

Two air outtake flues, each 4 feet square and built of two layers of matched flooring with paper between and fitted with doors, extend from the ceiling of the first and second stories through the roof and are capped with 36-inch metal ventilators.

The first story is not heated and most of the time, when ventilation is needed, there is slight temperature difference between the inside and outside air. Because of this condition it was found that the large outtake ducts, extending from the ceiling of the first story, were but partially effective, and the small temperature head even when augmented with an appreciable wind was not different in overcoming the added frictional resistance of the long flue. Oftentimes there are but a few hours at night or in the early morning when conditions are suitable for ventilating or cooling the first story and the circulation of large volumes of air is desirable. Hence substitution of air ports at the ceiling in place of the flues is recommended as a better means of ventilating the first story.

The third story is vented directly into four 36-inch ventilators. The results show that these may be decreased in size to 30-inch. Round metal ventilators were installed since slatted wooden cupolas are generally inefficient when the wind is blowing parallel to the long axis. Wind is a most important factor in ventilation of storage houses as the temperature head is usually small during the period when ventilation is most required.

Tight construction is essential. All sills and plates on masonry walls should be set in a good bed of mortar. The spaces between rafter ends and gable ends should be tightly closed to prevent air leakage. Moisture and sometimes frost collect at points of leakage and may cause early rotting of woodwork. Warm air leaking out, or cold air blowing in at these points has a material effect on room temperature and consequently on the amount of fuel burned.

Heating Equipment. The source of artificial heat must be reliable and of capacity sufficient to supply the maximum demand. Saving of fuel is desirable, but if secured at the risk of chilled potatoes it is poor economy.

The upper floors are heated by means of a steam boiler and pipe coil radiators on the north and south walls immediately above the air ducts. It was found that the steam wall radiation might be reduced approximately 25 per cent, providing 500 square feet in the top floor and 400 square feet in the second floor. A hot water system would possibly be more desirable as it requires less skill in operation and there is less likelihood of sudden changes in storage temperatures should the fire be neglected by the attendant.

The greatest amount of heat is usually required during the curing period when the outside temperature is generally below 60 degrees in this locality and large quantities of air must be heated to a temperature from 80 to 85 degrees. During the remainder of the storage period when a temperature of from 50 to 55 degrees should be maintained, the heating system need seldom be run at full capacity.

Conduct of Test. It was planned to compare the results of curing sweet potatoes at different temperatures on a commercial scale and to make observations on the presence, extent and development of disease in the stock stored. It was impossible to secure comparable stock for the latter purpose so that observations were not conclusive other than that the behavior of diseased stock has an important bearing on storage loss and should be carefully studied.

It was also desired to obtain data with respect to daily rate of moisture loss from the potatoes. Means were not available for weighing a number of barrels in each room, hence four one-bushel hampers of potatoes were placed in each room. These were weighed daily

during the first part of the test and later at five-day intervals.

Four hundred barrels of table stock, mostly of the Little Stem Jersey variety, were obtained from selected fields of four local growers, the condition of the fields with respect to disease infection being noted. Twenty barrels of each lot were placed at each of five stations in each room, one at the center and one in each quarter. The potatoes were delivered to the storage as they were dug; each barrel was weighed as it was stored and again at the end of the season, and the shrinkage noted. The total capacity of each of the two west rooms was 1400 barrels while the east rooms held 1600 barrels. The barrels were stored three tiers high.

In storing barreled stock ample alleys should be left so that any lot may be easily removed. Close stacking in corners where air circulation is poor should be avoided. Too close stacking is unwise as it prevents free circulation of air and may cause heavy loss of potatoes.

The weight of barrels when placed in storage ranged from 158 to 183 pounds, the average being 170.5 pounds. The average weight upon removal was 159.9 pounds, the average shrinkage being 10.6 pounds. The weight of empty barrels ranged from 16 to 21 pounds, the average being 18.1 pounds.

Temperatures and Humidities. It was planned to maintain a curing temperature of 75 degrees in Room A, 85 degrees in Room B and 80 degrees in Rooms C and D. The curing of sweet potatoes by means of artificial heat is a method of accelerating nature's process of eliminating excess moisture preparatory to a period of rest or dormancy and has been found quite effective in improving the keeping of potatoes in storage. In natural drying the moisture loss continues for a longer period and the shrinkage appears to be greater. When the drying is accelerated by artificial means, the excess moisture is driven off rapidly and the skin of the potato contracts and is toughened, acquiring a cork-like texture retarding further shrinkage. The length of curing period varies from 6 to 10 days or more depending upon the weather and the condition of the potatoes. The completion of the curing is evidenced by a velvet-like feel or the appearance of sprouts.

As each compartment is filled heat should be turned into it and the temperature raised to between 80 and 85 degrees. If the weather is dry and warm, a fire may not be necessary until the room is completely filled. This is desirable from the standpoint of the comfort of the men working in the room, but, if the conditions are such that the potatoes start to sweat freely and the natural ventilation is not sufficient to carry off the moisture, it will be necessary to turn on the heat before the room is filled. This calls for the exercise of judgment gained only through experience.

The control of air temperature and moisture is the most important consideration in the operation of a potato storage house. Since the relative humidity is dependent upon the temperature it is obvious that the first step is to regulate the latter by proper operation of the heating and ventilating systems.

As shown in Table I the average temperature in the respective rooms, during the curing period, very closely approximated the desired temperature. The average relative humidity being practically the same in each room the results, so far as the effect of temperature is con-

TABLE I. Average Temperatures and Humidities During Curing Period

Room	Average Temperature		Relative Humidity		Curing Period
	Out	In	Out	In	
	Degrees	Degrees	per cent	per cent	
A	60.7	75.1	69.0	64.8	8
B	63.0	84.5	69.8	63.7	6
C	58.0	79.2	68.8	62.3	6
D	58.0	80.9	68.8	63.4	6

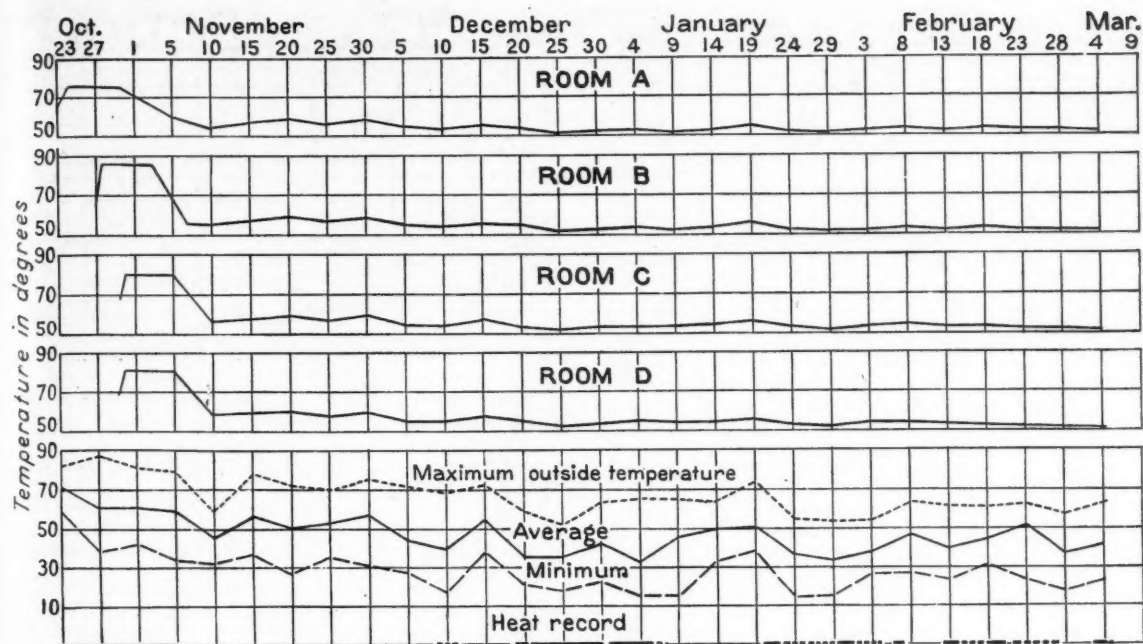


Fig. 2. Average temperatures for the entire storage period. The temperatures shown at five-day intervals are the averages, for that interval, of the daily average room temperatures and the maximum and minimum outside temperatures. The number of days during which heat was employed are shown by the bottom line. The dotted portions represent periods of slow firing when the fire was partially banked. The solid line represents continuous heating but not necessarily a heavy fire

cerned, are directly comparable. The curing period in Room A was two days longer than that in the rooms cured at higher temperatures.

Ventilation of the storage is necessary during the curing period in preventing accumulation of moisture, particularly when potatoes are stored in large lots. If the moisture is not removed, the drying of the potatoes is retarded, the moisture condenses on interior surfaces and the storage becomes damp, a condition conducive to the development of rot not only in the potatoes but in the structure itself.

The amount of air required for good ventilation will be greatest during the curing week. At this time a circulation of from 3,000 to 5,000 cubic feet of air is required to remove a pound of moisture, varying according to the atmospheric conditions.

In this house satisfactory results were obtained by using a flue area of approximately 1 square inch per barrel and during the curing week the air circulated at the rate of $1\frac{1}{2}$ to 2 cubic feet per minute per barrel. The high temperatures used at this time not only provide a greater temperature head for inducing ventilation, but also air of high temperatures has greater capacity for moisture and result in more rapid drying.

The relative humidity of the air during the curing process should be kept below 70 per cent so that rapid drying may take place. After the curing is completed the temperature should be reduced to between 50 and 55 degrees and so maintained throughout the balance of the storage period. The humidity during this period should not be less than 75 and not more than 85 per cent. Too high humidity is favorable to some rot organisms, while if it is too low excessive shrinkage results.

In cooling the house after curing the temperature should be reduced gradually over a period of 2 or 3 days depending upon the weather. It requires more time to cool potatoes and air within the barrels than it does to cool the room air. It was found that, if the latter is cooled too rapidly, its temperature may fall below the dewpoint of the air in the barrels and cause deposition of moisture on the covers and in the barrels.

In Fig. 2 are shown the average temperatures for the entire storage period. After the curing period and the subsequent cooling of the potatoes there was little variation in the temperature of the four rooms. The average was within the desired temperature range. By studying the weather reports and anticipating periods of favorable outside temperature it was possible to maintain the desired storage temperature much of the time without a fire.

Moisture Loss. According to the data presented in Fig. 2 the moisture loss, as determined by the weighing of hampers, was quite rapid for the first five days and continued at a marked rate until after November 10, by which time the potatoes had cooled to the desired holding temperature with an accompanying decrease in the rate of respiration. The loss of moisture continued throughout the storage period, there being an acceleration of the rate during the last four days at which time the potatoes were no longer dormant. There was but little difference in the rate of moisture loss in the several rooms until after November 18 when the rate in Room A became the greater and continued so until the end of the storage period.

Table II affords comparison of the moisture losses in the four rooms. The greatest loss, 14.4 per cent, occurred in Room A which was cured at a temperature of 75 degrees. The least loss occurred in Room D with almost 46 per cent of the shrinkage taking place during the curing period, the subsequent loss being at a much slower rate. There was but little difference in the percentage of loss in the hampers in rooms B, C and D. This would

TABLE II. Moisture Loss From Hampers

Room	Average Curing Temperature	Average Weights				Relation Curing Loss to Total
		In	Out	Loss		
	degrees	pounds	pounds	pounds	per cent	per cent
A	75.1	52.2	44.7	7.5	14.4	32.0
B	84.5	50.3	45.0	5.3	10.5	32.0
C	79.2	51.1	45.0	6.1	11.9	41.0
D	80.9	50.8	46.0	3.8	9.4	45.8

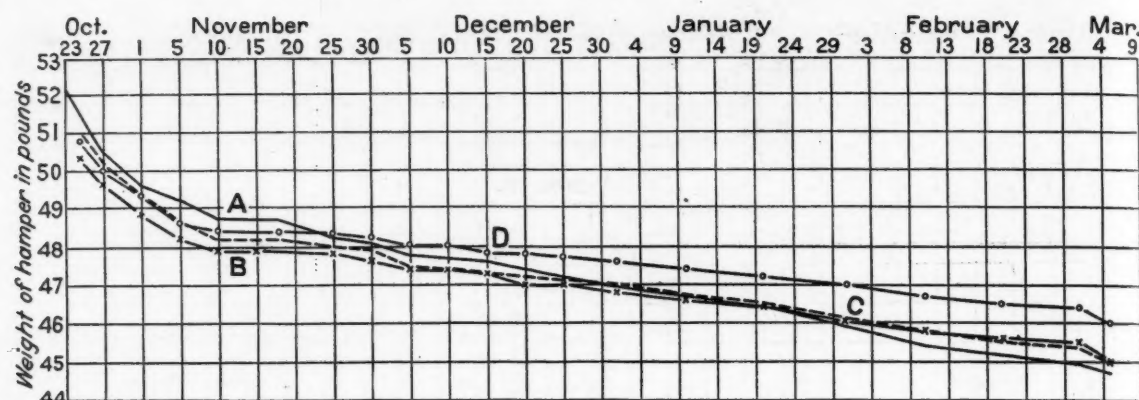


Fig. 3. Daily moisture loss from sweet potatoes stored in hampers

seem to indicate the desirability of hastening the moisture loss by curing at a higher temperature.

According to Table III the relationship of the several rooms with respect to the total moisture loss from the barrels was similar to that of the loss from the hampers, the greatest loss again being in Room A. The loss, for all lots, except 28, was greatest in Room A. The greatest shrinkage occurred, in most instances, in the top barrels and was the least in the middle tier. This was probably due in part to the greater fluctuations of temperature in the top barrels, which were secured by means of an electrical resistance thermometer, and in part to the greater circulation of air above the potatoes.

SUMMARY

Uniform temperatures, with reasonable control of humidity, can be maintained in sweet potato storage houses, such as described in this paper, provided that the operator appreciates the requirements of good storage, and will devote the time essential to proper observation

of air conditions and adjustment of the heating and ventilating systems.

The moisture loss from sweet potatoes cured on a commercial scale at a temperature between 80 and 85 degrees is less than from those cured at a lower temperature.

The storage reported upon is satisfactory in most respects, but certain improvements in design and construction would increase the efficiency of the building. The principal improvements are given in this paper but the details are omitted for lack of space.

TABLE III. Average Per Cent Shrinkage per Barrel by Rooms

Room	Owner				Weighted Average
	2	7	8	28	
A	9.37	7.57	8.84	8.26	8.51
B	8.06	6.76	5.76	6.51	6.77
C	7.01	5.32	7.02	8.33	6.92
D	6.42	4.85	6.01	6.97	6.06

Research Engineering¹

THE opening of a decade serves as a milestone where we should pause to review the economic progress of the preceding ten years. In America what has been the most outstanding economic development since January 1920? There will be many differences of opinion. We suggest consideration of the rapid increase in the number of research laboratories as being the most important economic development, if not during the past 10, then during the past 20 years.

As we recall it, less than a decade ago "The Chemical Engineer" took the U. S. Steel Corporation to task for not having a research laboratory. Now it has one. This sort of advance has become a common thing among big American corporations. The next decade will probably witness the wide adoption of research methods by American corporations, small as well as large.

In the January issue of "The American Magazine," there is an interview with C. F. Kettering, president and general manager of General Motors Research Corporation. Note the title of that corporation, and bear in mind that it is a subsidiary of the world's largest manufacturer of motor vehicles. Mr. Kettering is a "famous research engineer," to use the designation that appears in that interview. Note also that designation. Ten years ago the

title "research engineer" was almost unheard in America. Now there are probably several thousand who claim it.

"In his (Kettering's) laboratories at Detroit he uses his time and that of some 450 physicists, chemists, electrical engineers, mechanical engineers, mathematicians, and mechanics finding fault with General Motors products and thinking up ways to make them better and different."

About 14 years ago we gave the reason why the American Telephone and Telegraph Company had been able to perfect transcontinental telephony. ("Engineering and Contracting," November 29, 1916.) That article ascribed the successful solution of that telephone problem to the then novel practice of cooperative research, in which a new combination of brains was devised to solve the problem. The article was widely quoted because of the novel idea that it described—cooperative research.

Cooperative research even 15 years ago was not entirely new in Germany, for several manufacturers of chemical products had well-manned research laboratories. But shortly after the world war ended in 1918, when the du Ponts announced that they had organized a research laboratory that employed 3,000 technical men and assistants, there was open-eyed astonishment the world over. How could 3,000 researchers keep busy in any laboratory? That seemed incredible scarcely more than 10 years ago.

Many an engineer is dissatisfied with his economic prospects. To those that have a taste for research and

¹An editorial reprinted with permission from the March 1930 issue of "Engineering and Contracting," Chicago.

invention, a comparatively new field is open. How to enter that field we do not intend to discuss now.

Many a young man is contemplating taking an engineering course, but is in doubt as to the college to attend and the course to take. We suggest giving preference to a course and a college that offer good training in research methods. Unfortunately few colleges specifically provide such training, for it has been erroneously thought that inventors and discoverers are "born and not made," whereas the fact is that they are born and made. More often than not they are wholly self-made, but this was equally true to civil engineers less than a century ago. The Military Academy at West Point was the first American college to teach any sort of engineering, and it was founded in 1802, "and for about 30 years was the only organized agency for engineering education in America." In 1865 there were fewer than 300 graduates of American engineering colleges exclusive of West Point; yet this country even then had made great engineering progress, largely under the direction of self-made engineers. So it has been with our research achievements up till very recently; but at last it is beginning to be realized that

research engineering can be and should be taught as such.

When many young research engineers shall have been graduated, it will not surprise us if their achievements will revolutionize our present educational methods in every branch. After all, a college education accomplishes little that is worth while if it does not train a man to be a systematic, thorough investigator. So even now, the research spirit that is developed at college is the best part of any scientific training received there. However, that sort of training is usually a by-product when it should be the main product, regardless of the degree of native originality of the student or his intended occupation in after life.

Every one of us has at least a modicum of originality. Every one of us is competent to search for and classify information, and the great majority of us can draw correct inferences if we have secured adequate data. Research training develops such native originality as we possess; but even if it failed to do that, it would still be excellent training, for it would habituate men to get the facts and all the gettable facts. Unfortunately that sort of training is not yet very prominent in many of our schools and colleges.

Portable Dairy Coolers¹

By H. C. Parker²

REFRIGERATION has done as much or more than any other one factor in the advancing of the dairy industry in California. Through refrigeration the dairyman has been able to produce a better grade of milk with a saving of labor and time, thus cutting down to a very appreciable amount the cost of production. Without refrigeration, milk having a low bacteria count when produced, will increase to such a high count by the time it reaches its destination that it will be classed in Grade B.

A good example of this happened to one dairyman in Southern California. He has a refrigerating equipment which was doing his work very nicely and the bacteria count was ranging from 2000 to 5000. Then, due to some cause or another, the ice machine was out of order for several days so that he could not cool the milk down to the desired temperature. This ran up the bacteria count and under the system that he was selling his milk, it was dropped into Grade B for the whole month. His net loss, due to the difference in price of Grade A and Grade B milk, was \$1032.00 for that month.

This example does not prove that refrigerating equipment is absolutely perfect, but it does show what takes place when there is no method for cooling or holding the milk, or when inefficient methods are used, such as ice and salt.

At the California Milk Producers Laboratories in San Bernardino a sample of milk at 45 degrees temperature, and with a bacteria count of 5000, was divided into four equal parts. The first part was held at a constant temperature of 45 degrees for twelve hours. The bacteria growth was from 5000 to 7300, or an increase in bacteria count of 2300. The second part was held for twelve hours at 50 degrees and the bacteria count increased 5500. The third was held at 60 degrees for twelve hours, and the increase in bacteria count was 32,000 at the end of the period. The fourth portion was held at 70 degrees over a period of twelve hours, and the increase in bacteria growth was from 5000 to 8,000,000, an increase of 7,995,000.

This shows the necessity of cooling the milk down to a

low enough temperature so as to prevent the growth of bacteria. Bacteria growth is kept at a minimum when the milk is cooled to 40 degrees or below, and its most rapid growth takes place at about 70 degrees. We see that it is highly essential to have an efficient method for cooling the milk readily upon production, and controlling its temperature while in storage before shipment, in order to comply with one of the most important phases in producing clean milk.

For the small dairyman a cooler made into one complete unit is the most efficient, economical and serviceable, that is, a unit having a brine tank and storage compartment with the aerator mounted on the cabinet. The most efficient method for cooling milk is to use a double waterway cooler, circulating 70-degree water through the upper half of the aerator and brine at an average temperature of 22 degrees through the lower half of the aerator. As the milk is taken from the cow, it is poured into a reservoir from which it flows down over the tubes of the cooler in a continuous thin sheet and is collected at the bottom in the milk cans. If the milk is not shipped immediately, it is placed in the storage compartment which will keep the milk at a constant temperature of 40 degrees.

At this point it would be well to go into the various loads thrown on the ice machine during the milking period. We will assume that the equipment is full automatic, there being a brine thermostat in the brine tank. The thermostat is adjusted in such a way as to turn the machine on when the temperature of the brine has warmed up five degrees. Thus, if we start cooling milk with a 14-degree brine, then when the brine in the brine tank has warmed up five degrees, the machine will start. The machine itself will not carry the total load of the milk cooling and the brine will continue to warm up, but not nearly as rapidly as at first, and in all probability will not warm up to over 30 degrees during the entire cooling period. Then the machine will continue to run over a period of time until it has brought the temperature of the brine tank back down to 14 degrees, at which point it will shut off.

There are several types of dairies which must be considered, each requiring a different type of refrigerating plant. First, there is the dairy that ships its milk soon after each milking, or twice a day; second, the dairy that

¹Paper presented at a meeting of the Pacific Coast Section of the American Society of Agricultural Engineers held during the Pacific Slope Dairy Exposition at Oakland, Calif., November 18, 1929.

²Secretary, Parker Ice Machine Co.

ships once each day; third, that which retails its milk on regular milk routes; and fourth, not exactly a dairy, but the farmer who ships some milk or cream and who wishes to store meat, vegetables, etc., for his own use.

At the dairy that ships its milk twice a day, the milk is hauled away soon after cooling and due to this, there is no need of storage facilities, neither is there need for the making of any ice.

Now the dairy that ships only once each day will require storage facilities along with the milk cooling. The storage space needed must be ample to accommodate half the milk produced each day, in order to hold one milking over until the next when it will all be shipped.

The retail dairyman must be dealt with in a little different manner, in that he needs ice and storage both in his business. He must have ice to keep his milk cool during delivery and storage to hold over any surplus milk. The storage compartment must be made to accommodate milk bottle crates. The remainder of the installation will be the same as that of the previous types of installations.

On a small farm refrigeration must be used in such a way as to be most practical for all uses. The farmer needs a small storage to keep the fresh meat he butchers, the cream or butter that he intends to market, and his household provisions. He will probably want a little ice for ice water and beverages. In this case small ice cube trays are installed as are to be found in a standard household unit. With such an installation, the farmer has a place to keep all his provisions, both for his own use and those he intends to market.

In considering the general-utility cooler, there has been much discussion as to just what type of box or cooler would be suitable to meet the general requirements of the farmer. We had just such an occasion arise in our locality very recently. A producer was sold a complete outfit for cooling 200 gallons of milk, but there was no storage facilities, nor any ice making as he was shipping twice a day. He immediately inquired as to what he was expected to do with the meat he butchered and where he was to put small amounts of fresh fruits that he picked from time to time, to keep them until he could use them. We found that he did not need a large storage, such as a walk-in box, but he needed a small storage of the general-utility type. We designed a portable cabinet for him which will answer his requirements very nicely. Although he is shipping twice a day there is room on the bottom of the storage compartment to set four milk cans, and there are two shelves in the top part which he can use to store his meat, fruit, etc.

In the partition between the brine tank and the storage compartment, two ice cube trays are installed, which give him a sufficient amount of ice to use for ice water and cold beverages. In this one single portable cabinet, the man has his brine for milk cooling, cold storage, ice making and a general-utility storage compartment. As a rule the farmer does not need a larger storage capacity than this, but needs it for all purposes. Such a portable unit is more compact, neater and much more efficient than a walk-in box. The farmer could probably build his own storage box, more than likely a walk-in type, and he would save the price of a cabinet, but it would not be portable. The walk-in feature causes quite an additional heat load, as he has to open a large door and walk in, rather than open a smaller door and reach in for what he wants. Then the insulation would probably not be nearly as efficient; consequently, in the final analysis the amount which he would save by building his own box would soon be used up in additional operating cost due to longer operating time of the compressor, or even a larger machine for a job that a smaller one would do with the correct type of cabinet.

In all types of installations it has been found much more satisfactory from the producer's point of view, as well as from the manufacturer's, to use portable milk cooling cabinets. As has already been said, a portable

dairy cooler is much more compact, neat, clean and efficient. Not only that, but it is more readily installed, saving the expense of digging a pit for a brine tank, fittings and labor of installation. Then, too, cases arise where the dairyman wants to change his equipment around, move it to another locality, or outgrows the equipment installed, necessitating a larger outfit. If he has a portable cabinet, either he can dispose of it, or the dealer is willing to allow him a good trade-in price for it, as it is something that can be resold. With the built-in type of installation, dismantling the job depreciates the value as much as through previous use, and in the end it is worth little or nothing to anyone.

As time has gone along portable dairy coolers have come more and more into use until now nearly all installations consist of some type of a portable cabinet having any one or all of the facilities mentioned included in the one unit; namely, milk cooling only; milk cooling and storage; milk cooling, storage and ice making; milk cooling and ice making, and the general-utility type storage and cooler for use on the farm. Such cabinets can be furnished practically any size ranging from 80-gallon milk cooling per 24 hours and 40-gallon storage to 320-gallon milk cooling with storage for 36 crates or sixteen 10-gallon milk cans, and 150 pounds of icemaking per day. Where there is only milk cooling, standard portable cabinets for cooling up to 500 gallons of milk per day may be had.

A very important point in the sale of dairy plants is the increased cost of equipment where icemaking is required. By adding icemaking to the duty of the dairy plant, and by that I mean ice in 50-pound or larger blocks, the milk cooling capacity is greatly reduced. In the first place, in order to freeze the ice the average brine temperature must be held at approximately 15 degrees (Fahrenheit), whereas 30-degree brine will cool milk to 40 degrees very nicely, and for milk cooling only the average brine temperature may be 22 degrees. In order to maintain an average temperature of 15 degrees the brine will have a range from 10 to 20 degrees, and in order to get 10-degree brine a 15-pound suction pressure must be maintained on the compressor instead of 25 pounds, thereby cutting the compressor capacity fully 25 per cent.

The heat storage capacity in the brine itself is in direct ratio to the maximum and minimum temperatures, which in the case of the tank with icemaking, is from 10 to 20 degrees, or a 10-degree range, while that of milk cooling only is from 14 to 30 degrees, or 16 degrees range, giving the latter 60 per cent greater cooling capacity for the same volume of brine.

Analyzing the equipment cost we find that, by adding 100 pounds or so of ice to our tank, we must increase our compressor size, not only an amount to take care of the 100 pounds of ice, but 25 per cent on account of a reduction in suction pressure, and our brine tank must be enlarged fully 60 per cent in size to take care of the reduction in allowable temperature range. In designing such units we have found it advisable to incorporate the ice-making in a separate tank adjacent to the main brine tank, which overcomes somewhat these difficulties. Very few customers can understand the reason for the increased cost; therefore, our recommendation is to eliminate the ice entirely.

A word must be said about the small SO₂ portable dairy plants. We have sold quite a number for milk cooling and storage but no icemaking. The first cost on small dairies is undoubtedly less due to the small air-cooled equipment used. Time only will tell regarding reliability and cost of upkeep.

Too much emphasis cannot be laid upon the proper balancing of the machines, brine tank capacity, number of feet of coils, running time and suction pressure to be maintained on the machine. This is an engineering problem to be worked out on every size cooler, but once it has been solved it need never be worked out again.

A Temperature Study of Dairy Barn Floors¹

By Roy Bainer²

THE degree of warmth of floors made of different materials is more or less directly related to their thermal conductivity or heat-conducting qualities. The rate at which the heat is carried away from the cow by the floor determines whether or not the floor is warm or cold. If a material is used that has a high relative conductivity, heat will travel away from the surface very rapidly. This makes the floor cold. On the other hand, if the relative conductivity of the material used in constructing the floor is low, heat will travel away from the surface more slowly, resulting in a warmer floor.

Rather than make a relative conductivity test of each floor material, studies were conducted to determine the actual surface temperature of each material in place in the floor while the cows were on the floors.

Construction. Six common floor materials—earth, plank, concrete, building tile, creosoted pine block, and cork brick—were used in constructing the standing platform of the stalls. All concrete bases and subgrades were constructed from a mixture of one part portland cement, two parts sand and four parts broken stone. The rest of the barn floor, including gutter, allies and curb, was made of concrete. The testing equipment was installed in the north wing of the dairy barn of the Kansas State Agricultural College (Fig. 1).

The standing platform of two stalls was surfaced with the same material, so that the temperature readings could be taken in duplicate. The construction of each platform is shown in Fig. 2.

The standing platforms constructed of earth were replaced with concrete because of their unsanitary condition.

The standing platforms of Stalls 1 and 2 were constructed of a 5-inch layer of concrete over one layer of rubberoid roofing. The latter material was used to keep moisture from entering the floor from the subgrade and to act as an insulating agent.

The standing platforms of Stalls 4 and 5 were constructed of 2-inch planks laid over a 3-inch concrete base. The cracks between the planks were filled with asphalt.

The standing platforms of Stalls 7 and 8 were constructed of 4-inch building tile laid on a 3-inch concrete base. The tile were then covered with a 2-inch layer of concrete. The top layer of concrete was used to protect the tile against breakage.

The standing platforms of Stalls 9 and 10 were constructed of 2-inch cork brick laid over a 3-inch concrete

base. These bricks were made of ground cork and asphalt, molded into units about the size of ordinary bricks. They were laid on a bed of sand-cement mortar and the joints were grouted with mortar.

The standing platforms of Stalls 11 and 12 were constructed of 3-inch creosoted pine block laid on a 3½-inch concrete base. The blocks were laid on the base after it was given a coating of hot asphalt. After the blocks were in place, hot asphalt was poured into the joints between the blocks, making the platform waterproof.

Testing Equipment. Electric resistance thermometers operating on the thermocouple principle were placed in the surface of each floor in a position about even with the cow's udder when the cow was standing on the platform. The thermometer location is indicated by the dotted lines in Fig. 1. The thermometer bulbs, which were about 10 inches long, were placed across the platform parallel with the gutter. In addition to the thermometers located in the surface of each floor, two others were located in the subgrade to show any lagging of the subgrade temperature. Wires were run from each thermometer to a place where the temperature indicator could be connected and read without disturbing the cow.

The temperature-indicating device was a wheatstone bridge with the thermocouple in the floor as the unknown resistance of the bridge. The galvanometer was graduated so as to show the temperature of the thermocouple when the wheatstone bridge was balanced.

The thermometers were calibrated before and after each test. In this way all instrument and thermometer errors were corrected. The curves were plotted from corrected values.

Conduct of Investigation. Periods of extremely cold weather were selected for making the tests. In this way the influence of severe conditions on the floors was determined. Also the variations in floor temperatures were greater, which made comparison of the different materials much easier. Throughout the tests the temperature of the floors was taken hourly. Other things which had an influence upon the temperature, such as the cows lying down and getting up, and the opening and closing of windows and doors, were noted and recorded. The test was extended over a period of 24 days, divided into three tests of 4, 9 and 11 days, respectively. The temperature of each test was plotted and curves were drawn. By having three test one served as a check on the other.

The cows used throughout the test were heifers weighing approximately 800 pounds furnished by the Kansas State Agricultural College dairy department.

Analysis of Data. The results of the four-day run are shown in Fig. 3. The valleys in these curves show when the cows were standing up, while the peaks show

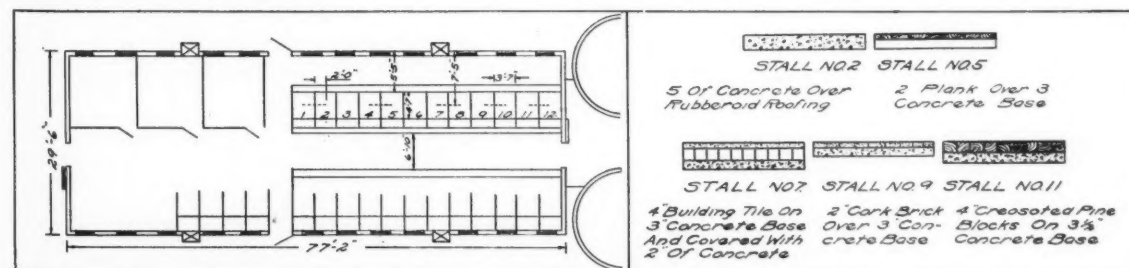
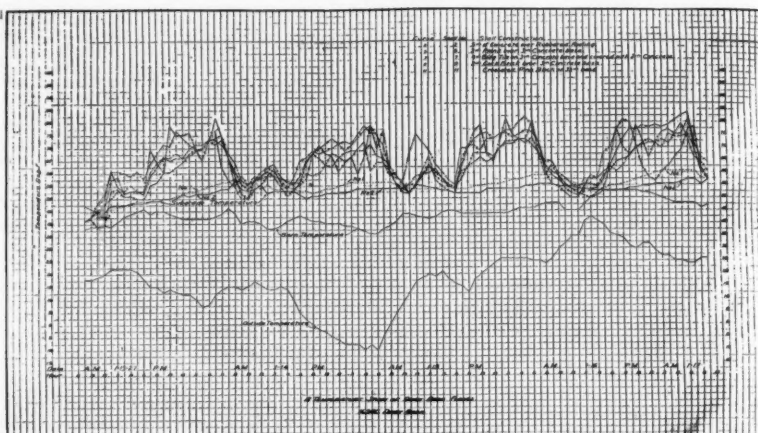


Fig. 1. (Left) Plan of the north wing of the K.S.A.C. dairy barn. The position of the thermometers in the stalls is indicated by the broken lines. Fig. 2. (Right) Sections showing construction of the stall platforms

Fig. 3. A graphic study of the temperature characteristics of various dairy stable floors during cold weather, as shown by a four-day test



the maximum temperature reached while the cows were lying down. All breaks in the curves are caused by the cow getting up or lying down. When the cows lay down, warming of the floor started immediately, and if the cows got up, cooling of the floors started immediately.

The rate at which the surface temperature raised is shown by the steepness of the curves. It will be noted that the temperature of the floors constructed of cork bricks, pine blocks and plank, (Stalls 5, 9 and 11) gave much steeper curves than those constructed of cement and cement and building tile (Stalls 2 and 7).

Temperature Studies. The maximum and minimum temperatures on the different floor surfaces did not vary a great deal so long as the cow's position on the different floors remained the same (Fig. 3). At feeding time when all of the cows were standing up, or when they were turned out of the barn, the temperature on each of the floors dropped to practically the same minimum level, regardless of whether the floor was made of concrete or cork brick. Likewise after the cows had been lying on the floors all night, the maximum temperature reached on all floors was about the same, the widest variation being not over 5 to 10 degrees (Fahrenheit).

The most important factor affecting the warmth of the floors was the rate at which they warmed up after the cows lay down on them. For example, two cows in adjoining stalls, one surfaced with concrete, the other with creosoted pine blocks, lay down at 8:00 p.m. By 10:00 p.m. the surface temperature of the pine block floor had raised from 50 to 80 degrees, a rise in temperature of 30 degrees in two hours, while the surface of the concrete floor never reached 75 degrees until 3:00 a.m. the following morning. A great amount of heat was required from 8:00 p.m. until 3:00 a.m., a period of 7 hours, and then the surface was not as warm as that on the other floor. Seven to eight hours were required to warm the concrete floor 25 degrees, as compared to warming the pine block floor 30 degrees in 2 hours.

All of the different floor materials have been compared to concrete, since concrete is a widely used and well-known material.

The floor containing building tile, while probably drier than the solid concrete floor, was no warmer (Fig. 4). It was just as slow to warm up as the concrete floor because of the 2-inch layer of concrete over the tile. This layer of concrete acted very similar to the solid concrete floor in that its conductivity was high, thus conducting the heat away from the surface and from the cow at a much more rapid rate than the cow was able to supply it. From the curve (Fig. 4) it will be noticed that the maximum temperature of 75 degrees was not reached until about 4:00 a.m. All of the breaks in the curves are traceable to the position of the cow, whether up or down. As long as she was down the temperature rose, and when

she stood up the temperature of the floor dropped. It will be noted, from the curve, that cows were up and down several times during the night. This of course slowed down considerably the warming-up process. The cows on these two floors got up oftener than those on the other floors.

The cork brick floor was considerably warmer than the concrete floor because of its low conductivity. Fig. 5 shows that only 3 hours were required for the cork brick floor to be warmed from 57 to 77 degrees, while 8 hours were required to warm the concrete floor the same amount. Other instances may be cited where the temperature rise of the cork floor was much higher, but this particular case is taken because the position of the cows on the two floors was practically the same. The rate of rise on the cork brick floor was about 6.6 degrees per hour, while the temperature rise on the concrete floor was only 2.5 degrees per hour.

A comparison of the temperatures of the creosoted pine block floor and the concrete floor is shown in Fig. 6. These curves were chosen because at this particular time the position of the cows on these two floors were particularly the same. The temperature rise for the two floors during the first hour after the cow had lain down was 15 degrees for the pine block floor and about 7 degrees for the concrete floor.

The minimum temperature of these two floors is shown to be about the same at 6:00 p.m., while the maximum temperatures differed only about 10 degrees between 4:00 and 5:00 a.m. Even though the maximum and minimum temperatures were very nearly the same, the block floor is shown to be much warmer in that within one hour the temperature on the floor was 70 degrees, while 7 hours were required before the temperature on the concrete floor reached 70 degrees.

A comparison of the temperatures on the pine plank floor and the concrete floor is shown in Fig. 7. The temperature on the plank floor rose from 52½ degrees to 70 degrees in 2 hours, a rise of 17½ degrees. On the other hand, 7 hours were required to bring the temperature of the concrete floor from 55 degrees to 70 degrees. Again it is shown that there is not a great deal of difference between the maximum and minimum temperatures of the two floors.

The curves in Fig. 8 were drawn to show a comparison of the temperature on the cork brick and pine block floors. This example was used not because of any outstanding rise in temperatures, but because the cows on these two floors were up and down through practically the same periods of time. In making comparisons of the different floors, it was rather difficult to find periods when all the cows were lying down or standing up at the same time throughout the night.

In making a study of these two floors it was found that

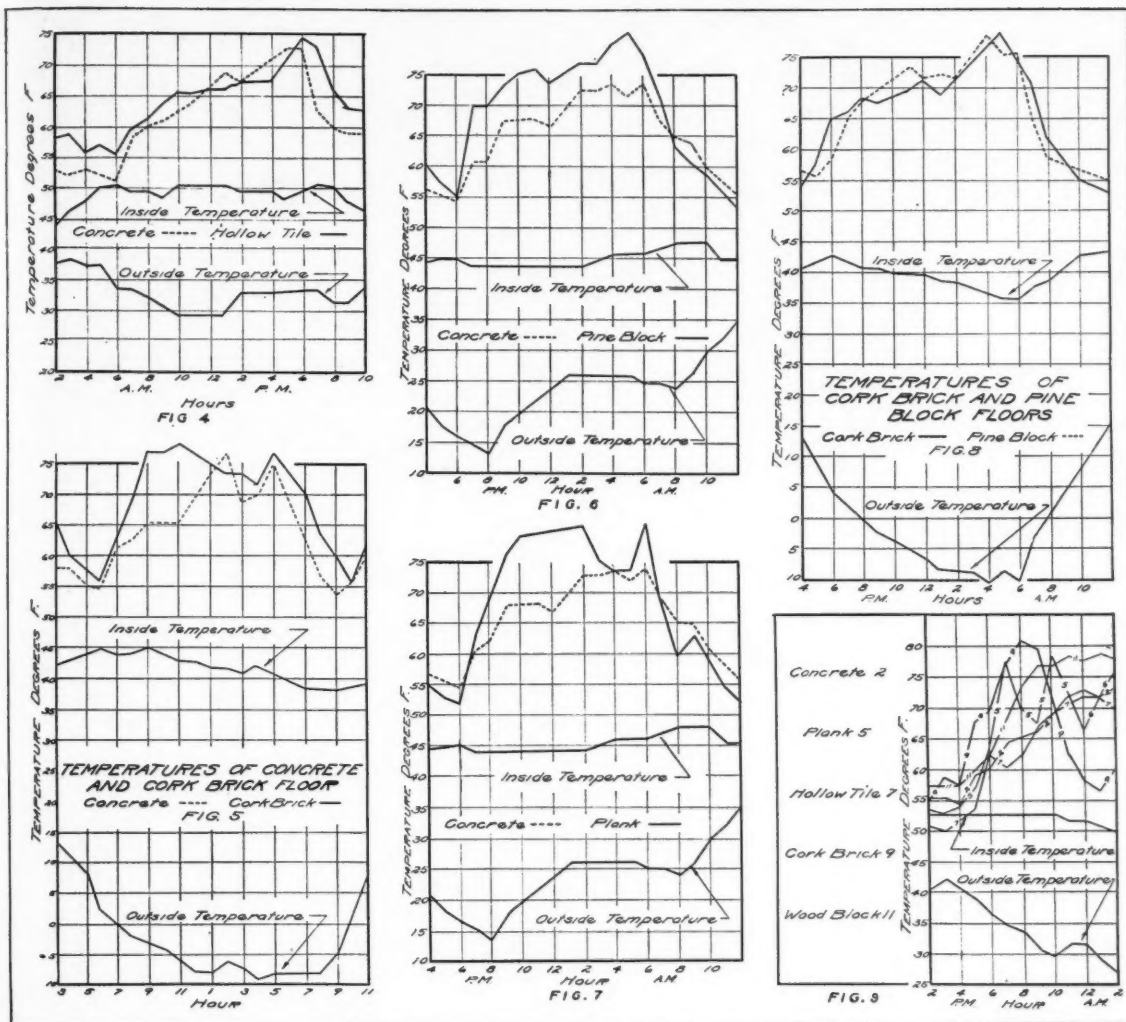


Fig. 4. Curves showing temperatures of concrete and hollow tile floors. Fig. 5. Curves showing temperatures of concrete and cork brick floors. Fig. 6. Curves showing temperatures of concrete and pine block floors. Fig. 7. Curves showing temperatures of concrete and plank floors. Fig. 8. Curves showing temperatures of cork brick and pine block floors. Fig. 9. Curves showing temperature rise in stall floors of various materials

the surface temperatures were practically the same. This indicates that the heat-conducting qualities of the two materials were about equal. So far as warmth was concerned, there was little in favor of one material over the other.

The curves in Fig. 9 were drawn to show the steepness of the curves, which is an indication of the rate of warming for the different materials. Here the temperature is shown to rise much faster on the plank, cork brick and pine block floors (Stalls 5, 9 and 11, respectively) than on the concrete and concrete building tile floor (Stalls 2 and 7, respectively).

The rate of temperature rise on the first three floors mentioned is shown to be about the same, and the rise on the other two is about the same. A relatively short time is required for warming the floors constructed of these materials as compared to concrete and building tile.

CONCLUSIONS

1. Whether or not dairy barn stalls should be surfaced with a material having low heat-conducting char-

acteristics depends upon the winter temperature of the region in which the barn is located.

2. For Kansas conditions a floor constructed entirely of concrete would probably be more practical since the temperatures in the state are hardly ever below zero. If zero weather does occur, it is of very short duration. During these periods a heavier bedding might be used over the concrete floor, thus providing a warmer place for the cow to lie.

3. In states farther north where low winter temperatures of long duration are encountered, stall materials of low heat conductivity might be used, thus providing a much warmer floor.

4. The cost of cork brick and wood blocks is approximately 50 cents per square foot. Material for covering cow stall floors will be approximately 50 cents per square foot. Material for covering cow stall floors will be approximately \$5.00 per cow. If this cost is distributed over the usual term of service the yearly cost per cow is very small.

5. For general farm use it is unnecessary and inadvisable to cover the entire barn floor with wood blocks

or cork brick. Instead the standing platform should be of this material, and the remainder of the floor, the gutters, alleys and mangers, may well be of concrete. By using wood blocks or cork brick in the stall only, the cost of their installation will be only a fraction of that for the entire floor.

6. Although a floor constructed of wood plank is much warmer than a concrete floor, it is insanitary, is relatively short lived, and when worn offers a possibility of injury to stock from splinters. Its unfavorable features out-

weigh its favorable ones, so this material should be considered as unsuited to the purpose.

7. The life of a floor made of creosoted pine block is about twice that of one made of cork brick; however, a wet cork brick floor is not as slippery as one made of pine block.

AUTHOR'S NOTE: The author wishes to acknowledge, with gratitude, the suggestions and criticisms of H. B. Walker, formerly professor and head of the department of agricultural engineering, Kansas State Agricultural College, and R. H. Driftmier, professor of agricultural engineering, of that institution.

The Cost of Farm Buildings¹

By Deane G. Carter²

THE wide range of location, types, requirements and sizes of farm buildings offers difficulty in developing any method of cost analysis that will afford a basis for approximate estimates. Obviously, a great deal of data would have to be accumulated to establish cost data, and for the most part reliable data can be secured only by an award of contracts and actual construction.

The demand for cost data, however, justifies the presentation of comparatively few cases. Applied to local conditions these data may offer some assistance in arriving at the approximate cost of the common farm structures.

The author's article, entitled "A Study of Farm House Costs," appearing in the June 1929 number of *AGRICULTURAL ENGINEERING* (Vol. 10, No. 6) indicated the cost of typical modern, six-room, well-equipped houses at 21.5 to 25 cents per cubic foot under Arkansas conditions. Additional construction, since handled, tends to confirm these costs, although under other conditions, particularly in the larger cities in the east, the cost may be practically double.

The costs presented herewith are for buildings planned and construction supervised by the Agricultural Engineering Department of the University of Arkansas college of agriculture. In most cases the costs are the lowest of several bids submitted; if not contracted, the actual cost of material, labor and supervision has been used. From one to seven structures of each class were built in five separate localities in Arkansas over a period of four years. The type of construction is that ordinarily recognized as standard, with no "cheap type" of buildings included. All the structures have composition shingle roof, dressed, matched, and painted exterior, sound framework, with such

building equipment as would be considered necessary for a satisfactory job. In general the construction is somewhat better than is found on the average farm, but the buildings are entirely suitable as practical farm structures. Variations in construction or equipment are noted for each group analyzed.

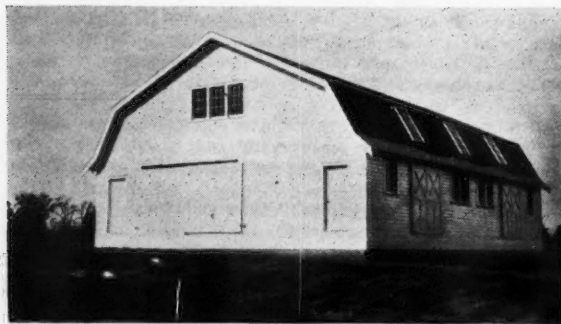
Poultry Houses. These are of the shed-roof, open-front, unit type, with feed room, 20-by-20 feet in size, concrete floor, equipment built in, pine framing, matched siding, heavy composition roof. One building of this group, on a contract price of 9.6 cents per cubic foot, 67 cents per square foot, cost \$268.00 total, or \$2.68 per bird.

Individual Hog House. This is an A type, 7-by-6-foot, Nebraska house, without floor, pine frame, No. 1 boards, metal battens. Based upon several houses built in the laboratory, the total cost was \$9.50 per house, or for each sow and litter unit, 9½ cents per cubic foot, or 22.6 cents per square foot area.

Utility House. This is a garage type structure, 10-by-16 feet, for use in connection with cottages for wood storage, general storage, small poultry flock, and includes ceiled-off toilet space with separate entrance. Concrete floor, completely finished to match adjacent houses. Four, built under identical conditions, cost \$200.00 each, 13.9 cents per cubic foot, or 1.25 cents per square foot.

Sweet Potato Curing House. This 16-by-20 feet in size, double floors, insulated walls, 700-bushels capacity, brick flue, Celotex insulation, all frame on concrete piers, to wagon bed height. One built on contract at lowest of several bids cost \$717.00; 13.2 cents a cubic foot, \$2.22 a square foot, or \$1.00 per bushel of storage capacity.

Products Storage Building. This includes seed house, cotton storage, rice and grain storage. Two-story construction, concrete first floor, frame second floor, overhead grain storage, bins, and working space, gambrel roof. Heavy construction and many partitions, as compared to a plain shelter building. Three buildings were



(Left) This fruit and vegetable grading and packing house on the Fruit and Truck Branch Experiment Station at Hope, Ark., is typical of the frame construction costing approximately 6 cents per cubic foot. (Right) Machinery storage and barns typical of the better class of buildings analyzed in the Arkansas study of building costs

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(Left) This is the 100-foot, low-loft dairy wing on the main experiment station farm at the University of Arkansas. (Right) The cotton experimental building located at Marianna, Arkansas

erected, with considerable variation in character, size and use. The largest and most complete cost 5.88 cents per cubic foot, \$1.61 per square foot, or \$43.50 per lineal foot 30 feet wide for good two-story and roof construction. A much smaller structure, tall, and heavily built cost 7.45 cents per cubic foot, and \$2.22 per square foot. It is probable that normal grain storages will cost 6 cents per cubic foot under like conditions.

Machine and Equipment Storage. In size these structures were 30 to 40 feet wide, and 60 to 68 feet long, 1½ story, with ground floor and loft, gambrel roof, well braced for fruit and vegetable handling or shop and machinery building. Results are based upon five buildings very similar in size and construction. The cost varied from 4.95 cents per cubic foot to 7.60 cents on a high contract price. Three on normal costs were 5.50, 6.30, and 6.50 cents per cubic foot, respectively. The approximate average is 6 cents.

Tile Barns. These are for dairy stock, work stock, feed, hay, and pens. Two-story height, tile in first story, concrete floor, steel equipment, composition shingle roof, gambrel roof shape, fully modern, width 34 to 36 feet, length 55 to 124 feet, some variation in height. Five of the barns were very similar in type of construction, and cost 6.22, 6.44, 6.55, 6.85, and 9 cents per cubic foot, respectively. The 9-cent cost was on a barn with a low loft capacity. Very little additional material and labor would have brought this barn to the same height, in which case the cubic foot cost would have approximated 6.5 cents, thus establishing the barn cost at about 6.5 cents. The cost per lineal foot ranged from \$57.50 to \$74.00, and the square foot cost from \$1.69 to \$2.07.

Frame Barns. These are for livestock, feed and hay storage similar to tile barns, except concrete floor omitted, and oak used in framework where not exposed to weather. Estimated costs on two frame barns, where part of the material and labor was furnished by the farm and with plain equipment, were 4.2 and 5.45 cents per cubic foot and \$1.17 and \$1.40 per square foot.

Conclusions. The conclusions based upon approximately twenty-five structures are as follows:

1. The cost per cubic foot decreases as the volume of the structure increases.
2. Added height has a much smaller effect on the total cost than either width or length.
3. Bid prices remain fairly constant under uniform factors of material, labor and transportation regardless of locality. It is impossible to estimate accurately for a special location.
4. Typical larger farm structures, such as barns, machinery buildings, and grain storages (of normal sizes and capacities) cost approximately 6 cents per cubic foot.
5. Because of lesser volume and lack of equipment, the

machinery, products and grain storages cost less in every case than the barns on a square-foot basis.

6. The addition of the tile walls and steel equipment, while adding to the cost to some extent, does not represent a very large proportion of the total.

Costs. Approximate costs for typical farm buildings may be calculated as follows:

Individual hog house, \$9.50 each

Poultry house (tentative), \$2.50 to \$2.70 per bird

Utility house or garage, \$200, or 13.9 cents per cubic foot

Sweet potato storage, \$1.00 per bushel capacity

Grain or products storage, 6 cents per cubic foot

Machinery, Shop and Storage, (1½ or 2-story), 6 cents per cubic foot

Barns, complete and well equipped, 6.5 cents per cubic foot

Houses, 2-story and basement, frame, modern (previous report), 21.5 to 23.5 cents per cubic foot.

Local Costs. The construction of the buildings was, under conditions of common material and labor costs, as follows:

Common labor, 25 cents per hour

Carpenter labor, 65 to 85 cents per hour

Mason, \$1.00 per hour

Plasterers, 16 cents per square yard

Painters, 70 cents per hour

Cement, 65 cents per sack

Gravel, \$1.75 per yard

Sand, \$3.00 per yard

Brick, \$16.00 per thousand

Dimension, \$27.50 per 1000 feet

Shiplap, \$30.00 per 1000 feet

Siding, \$50.00 per 1000 feet

Flooring (oak), \$75.00 per 1000 feet average

Roofing, \$6.00 to \$14.00 per square

Kind of Building	Width, feet	Length, feet	Area, sq. ft.	Height, feet	Volume, cu. ft.	Cost per cu. ft., dollars	Cost per sq. ft., cents	Total cost, dollars
Individual hog house (A type)	7	6	42	2	84	0.288	9.50	9.50
Poultry house (unit type)	20	20	400	7	2800	0.670	9.60	268.00
Utility house (garage and storage)	10	16	160	9	1440	1.05	13.90	200.00
Sweet potato house (insulated)	16	30	500	17	8400	0.22	13.20	717.00
Products storage	30	50	1500	24	36000	1.08	4.50	1612.00
Seed house	30	48	1440	37	53280	0.76	7.90	3868.00
Cotton house	24	54	2916	24	77760	1.01	6.90	4692.00
Machinery and Equipment	30	66	2040	20	40800	1.50	6.50	2658.00
Machinery and shop	30	68	2040	20	40800	1.52	7.80	3097.00
Machinery and shop	30	68	2040	20	40800	1.56	6.30	2580.00
Fruit packing and storage	40	60	2400	20	48000	0.99	4.95	2376.00
Fruit packing and storage	40	60	2400	20	48000	1.10	6.50	3120.00
Tile barns -								
General-purpose	36	122	4392	30	131760	0.67	6.88	9000.00
Dairy	36	100	3600	30	108000	1.80	9.00	6500.00
General-purpose	34	55	1870	27	50490	1.79	6.55	3350.00
General-purpose	34	61.5	2094	27	56586	1.75	6.44	3400.00
General-purpose	34	65	2210	27	60330	1.69	6.18	3762.00
Frame barns -								
Barn	36	72	2592	31	80352	1.40	6.70	3400.00
General-purpose	32	54	1728	24	41472	1.17	5.45	900.00

Agricultural Engineering Digest

A review of current literature on agricultural engineering by R. W. Trullinger, specialist in agricultural engineering, Office of Experiment Stations, U. S. Department of Agriculture. Requests for copies of publications abstracted should be addressed direct to the publisher.

The Combine Harvester in Minnesota. A. J. Schwantes, R. H. Black, Et Al. (Minnesota (St. Paul) Station Bulletin 256 (1929), pp. 50, figs. 11.)—The results of an investigation of the status and use of the combine in Minnesota agriculture are presented in considerable detail. The work was done by the station in cooperation with the U. S. D. A. Bureaus of Agricultural Economics and Public Roads.

Plump, hard spring wheat kernels that are sound and normal will ordinarily remain sound and cool throughout the fall and winter if they do not contain more than 14.5 per cent of moisture. With shrunken, soft, or sprouted grain, the safe moisture limit is probably 0.5 to 1 per cent lower than that. The safe maximum limit is lower for oats and barley than for hard spring wheat, being not more than 13.5 per cent. Harvest should be delayed until the moisture content of the grain has dropped to about 14 per cent. All varieties of the same cereal required about the same time to reach the stage for safe harvesting with the combine. Not quite so much moisture is taken on during the night by grain in the windrow as by uncut grain, hence combining might be possible earlier in the morning from the windrow than from standing grain. On the other hand, standing grain dries more rapidly after rains than grain in windrows.

Weeds are one of the outstanding hindrances to successful combine operation. The majority do not ripen until after the grain is harvested, although seeds have formed in most of them. These seeds contain from 20 to 60 per cent of moisture, depending upon the relative maturity of the plants. The percentage of moisture varies with the season and the locality, and the variety of weed. Windrowing is almost indispensable in very weedy fields.

Barley was less adapted than oats for harvesting with the combine, as far as lodging was a factor. All varieties lodged badly at University Farm and Morris before they were ready to harvest with the binder. The lodged barley reached the 14 per cent moisture stage somewhat later than did Gopher oats, the straw of which stood erect. Crinkling and shattering, particularly after heavy rains, caused most of the reduction in yields. Oats lodged less than barley, but crinkling and shattering started soon after they became dead ripe and were the main factors responsible for reductions in yields. Wheat lodged less than the barley varieties and crinkled and shattered less than either barley or oats. This enabled the wheat to stand in the field through heavy storms after it was dead ripe with less marked decreases in yield. The losses that occurred were due to crinkling and consequent loss of spikes rather than to shattering. Loss of bolls caused most of the reduction in yields of flax. Losses due to lodging are much higher when harvesting with the binder than when harvesting with the combine. The combine harvester picks up lodged grain fully as well as the binder. When lodged grain is cut with the binder and bound, subsequent losses are heavy because bundles can not be made properly. As there is no possibility for losses after cutting with the combine, lodging becomes much less important.

If the moisture content of grain harvested with a combine is 14 per cent or less at time of harvesting, no special precautions need be taken in storing. If it is necessary to harvest with a combine grain that contains a little too much moisture, the grain can usually be safely stored in properly ventilated bins. Grain harvested with a combine should always be cleaned before it is stored if it contains green weed seeds. It can not be safely stored even in ventilated bins.

Data are also given on harvesting and threshing losses, combine adjustment and care, and on combine harvesting cost.

Adobe Construction. J. D. Long (California (Davis) Station Bulletin 472 (1929), pp. 56, figs. 35.)—The results of experiments with adobe construction conducted at the station over a considerable period of years are reported. In the course of these the practical and economical value of earth as a construction material for small structures in California has been proved through the actual erection and use of such structures. The use of sundried brick, rammed earth, and poured earth are the three methods of incorporating earth into the walls of farm buildings of the State which appear practical. It has been found that the apparent strength developed in test specimens and the amount of cracking occurring as the mud dries can be used as an index to the suitability of the soil.

Earth wall construction is inferior to most standard construction materials in earthquake resistance, but adobe structures have withstood earthquakes in the state with little or no apparent damage. Skillful and intelligent workmanship and

the incorporation of certain reinforcing design features help to minimize the damaging effect of earthquakes. A protective coating should be used on adobe walls to guard against moisture and mechanical wear. Cement, lime and mud plasters, and various paints have been used with success. The advantages of adobe are that it is a native material of adequate strength and durability for residences and small structures, and a material generally economical to use. Attractive, sanitary, comfortable, fire-resistant, dry, sound-proof, and thermal insulated structures may be erected of the material.

The principal disadvantages attending the use of the material are the following: A large amount of physical labor is involved in such buildings. The low tensile strength requires particular care in securing door and window frames. Additions or alterations in the plan after the work is once started are difficult.

The cost of earth wall structures varies widely under different conditions. In the state the complete cost of an adobe residence, including items for all labor, commercial materials and equipment necessary to make the structure available for use, is about the same as for a wood-frame structure of similar quality.

[Agricultural Engineering Studies at the Illinois Station] (Illinois Station (Urbana) Report 1929, pp. 108, 189-208, figs. 5).—Tests by C. W. Crawford and E. T. Robbins of the pulling power of 144 different teams indicated that weight is one of the first essentials in a team used for pulling big loads. Horses making good records also were energetic but not flighty in disposition, were well trained, carefully hitched and well shod. The results showed also that in a group of horses of equal weight, those with the greater heart girth exerted the greater tractive force. Horses also must be in good flesh to do their best. A good disposition is a valuable asset, and a skillful driver is as necessary as good horses. Barefooted horses were unable to hold their own with well-shod teams.

The results of a study by E. W. Lehmann of sludge accumulation in three isolated septic tanks are presented and discussed. These indicate that there is an unloading of sludge under certain conditions. This apparently occurs in tanks that are functioning properly with a normal discharge through the tank.

The results of tests by R. I. Shawl of eight oils for tractor lubrication indicated an apparently close relation between the ability of an oil to resist crank-case dilution and the number of hours it can be used in an engine.

Tests of corn borer control machinery and practices, by Shawl, A. L. Young, and R. B. Gray of the U. S. D. A. Bureau of Public Roads, indicated that plows equipped with properly adjusted jointers, covering wires and full-size, or better, extra-large coulters, will cover cornstalks far better than when equipped only with small worn coulters. Other conditions being the same, large-bottomed plows will cover slightly better than the smaller bottoms. In general, some treatment of the stalks previous to plowing such as disking, rolling, breaking with a pole or harrow, or raking and burning, will permit a plow to do better covering. Soil conditions, particularly the amount of moisture, influence the extent to which trash can be covered, as well as the quality of plowing. Jointers of the right type aid tremendously in getting good covering, particularly when used in conjunction with covering wires. Proper hitching, proper adjustment of coulters and jointers, and correct placing of wires are essential. Fields in which livestock had been pastured showed a higher average count than those not pastured, although some exceptionally clean fields were ones that had been heavily pastured when muddy. There appeared to be no difference between fields plowed with tractors and those plowed with horses. Plows equipped with weed rods or covering wires did no better work than those not so equipped, indicating that these are of little value unless carefully placed and adjusted.

The combine tests by Young indicate that the amount of grain lost should not be the deciding factor in determining whether or not combining should be substituted for the binder-thresher method of harvesting small grain, not including soybeans. The quality of grain obtained and the cost of harvesting are probably more important. In combining, those conditions or methods of operation that turn out grain of good quality will also tend to decrease losses.

The studies by Lehmann, Young, W. L. Burlison and G. H. Dungan of artificial drying of crops indicated that when

drying wheat by blowing heated air through layers of varying thickness under given conditions there is probably one thickness of layer that is most favorable. An attempt to dry a fairly large batch of ear corn revealed the difficulty of securing uniform and complete drying. The drying of small samples of ear corn, shelled corn, wheat and oats in air having a constant velocity, temperature and humidity showed that the moisture content of small grain and shelled corn can be reduced much faster than that of ear corn, and that the rate of drying is more rapid when the moisture content is high. Tests made on the shrinkage of cribbed corn revealed that ear corn reached its driest condition in July, as an average of three two-year tests. The factor that had most to do with the degree of shrinkage was the percentage of moisture in the corn at the time of cribbing. Rainy weather and high atmospheric humidity retarded shrinkage in newly stored corn, and increased the rate of water absorption in corn during its second year of storage. The wide fluctuation in shrinkage from month to month indicates that corn absorbs moisture rather readily.

Data are also included and discussed on corn production with mechanical power, draft requirements of corn borer plows, soil erosion, and housing hogs and poultry.

Unit Electric Plants for Nebraska Farms. E. E. Brackett and E. B. Lewis (Nebraska Station (Lincoln) Bulletin 235 (1929), pp. 28, figs. 9).—The results of a survey of present conditions and a study of 30 different makes of battery-type plants, 2 makes of automatic type, and one semi-automatic type in use for ordinary purposes on Nebraska farms are presented. The plants range in size from 600 to 3,000 watts. The 850-watt size was the most common battery-type plant and the 1,500-watt size the most common automatic type found. Farmers having battery-type plants reported a total of 29 different uses for electricity, while those having the automatic type reported a total of 36 different uses. It was found that increasing the number of uses of electricity from a plant apparently did not shorten its life. The oldest battery-type plant from which data were secured was 20 years old, and the average age of all battery plants investigated was 6.16 years. The oldest automatic plant studied was 7 years old. The range in the age of battery-type plants reported worn out or discarded because badly worn was from 7 to 11 years. Plants on which careful measurements of fuel and oil consumption were made showed costs of from 11.7 to 15.25 cents per kilowatt-hour for fuel and oil when averaged over a period of one year under ordinary service to the owner. The average life of batteries reported worn out in service was 6.03 years. The 80-ampere-hour battery had shorter life than the 160-ampere-hour battery when discharging for the same number of uses of electricity, but the estimated cost of charging was much the same and the initial cost of the 80-ampere-hour battery was much less. Batteries worn out in service as starting batteries on automatic plants had an average life of 2.4 years.

The Application of Steam for Heating and Sterilizing Dairy Equipment. A. W. Fayrall (Journal of Dairy Science, (Baltimore) 12 (1929), No. 2, pp. 95-113, figs. 15).—The results of experiments conducted at the California Experiment Station and presented at the June, 1928, meeting of the American Dairy Science Association at Madison, Wis., on the use of steam for heating and sterilizing dairy equipment are reported.

It was found that the most important properties of steam which affects its use as a sterilizing medium are that the temperature of the saturated steam increases with pressure and may be raised by superheating, and that superheated steam absorbs moisture.

Equations are developed which state the relationship between the factors involved in the thermal exchange which takes place when milk cans are steamed. The heat-absorbing capacity of a milk can is limited by the area of the surface, the coefficient of heat transfer, and the temperature difference between it and the heating medium. It is unnecessary to use any more steam than just enough to maintain the temperature of the heating medium inside the can, and to give the necessary turbulence, to insure a good coefficient of heat transfer.

Wet and saturated steam heated the cans at higher rates per degree difference in temperature between the can and the steam than did the superheated steam. Higher final temperatures of the can were obtained when superheated steam was used. With a spreading type jet made by drilling a hole in a 0.5-inch pipe, the temperature in the can metal varied about 14.6 degrees (Fahrenheit) after 15 seconds' steaming, and varied about 5.7 degrees at the end of a half-minute steaming period. The hottest part of the can was near the junction of the sides and bottom.

Steaming with superheated steam left much less moisture in the can than when saturated or wet steam was used. The use of superheated steam in the last steam jet of a continuous can washer assists in drying the cans.

The time-temperature curve, showing the rate of temperature rise of milk cans when heated over steam jets, rises rapidly to a point where it flattens out sharply as the temperature is reached when there is equilibrium between heat supplied and heat radiated.

Milk cans when heated slowly in a steam-heated tank-type ster-

ilizer, follow the sterilizer temperature closely. Milk cans when heated slowly in a hot air heated tank-type sterilizer lag behind the temperature of the sterilizer to a considerable extent.

Tests of Green-Cut Western Cedar Poles. R. S. Perry and T. A. McElhanney (Canada Department of Interior (Ottawa) Forest Service Circular 21 [1927], pp. 8, fig. 1).—The results of a number of mechanical tests are reported which dealt with green-cut sound western cedar poles and with small test specimens cut from them after breaking.

The results indicate that the number, extent, and location of defects has a noticeable effect on the strength of the pole as a unit. Soaking the butt of the pole brings the point of failure very close to the load (ground) line, but complicates the study of the effect of moisture content on the strength.

The small clear static-bending tests serve to check the values of modulus of rupture found from the pole tests; they show that the high values were not due to low moisture content or to variations in the sectional moisture content of the pole but to the strength of the wood itself; they indicate the effect of defects on the pole. All the small tests show material of a higher specific gravity than that from old-growth Western cedar. They confirm the fact that higher strength values are obtained from pole-size trees than from mature timber.

[Energy Requirements, Capacities and Characteristics of the Cutters and Grinders used for Processing Foods] (Kansas Station, Fort Hays Substation [Pamphlet], 1929, pp. [8-12], figs. 2).—The results of a series of tests run on several different silage cutters and hammer mills in connection with feeding experiments are reported.

The most important single factor affecting the energy requirements of the silage cutters was the speed at which the elevating fan was operated. If the speed was excessive, energy was wasted in overcoming air friction. An increase in speed gave a relative increase in capacity, but experiments indicated that when the speed was doubled the power consumption increased approximately seven times due to the increased air friction. Four hundred to five hundred revolutions per minute, when maintained, was sufficient speed to operate any of the cutters while elevating into a 40-foot silo. Sharpness of knives was next in importance in the operation of the silage cutters. The energy for cutting kafir silage into 0.25-inch lengths increased approximately one per cent for every ton load that passed through the cutter. The increase in power consumption was 35 to 60 per cent for dull knives over sharp ones, depending upon the material cut. There was a greater tendency for the knives to dull when the cutter was operated at the higher speeds, due to the greater impact with which the knives hit the bundles.

The capacities of the cutters varied from 5 to 15 tons per hour, using a 10-horsepower motor. The amount cut depended upon the condition of the material and the length cut. The capacity increased about 35 per cent for a 0.5-inch cut over a 0.25-inch cut. The men were required to operate the hammer grinders, one to cut bands, divide bundles, and place them within reach of the feeder, while the other did the feeding. On the other hand, only one man's time was required for feeding the combination grinder because of the excellent feed table with which this mill was equipped. It was impossible to maintain uniform feeding into those mills which were not equipped with some type of feeding mechanism. Consequently, due to this unevenness of feeding, the average capacities secured were not the maximum capacity of the mill.

The cost of grinding was about 70 per cent greater for the hammer type mills than for the combination knife and burr mill.

The Strength of North American Woods. H. S. Betts (U. S. Department of Agriculture, Miscellaneous Publication 46 (1929), pp. 18).—The mechanical properties of 129 different woods grown in the United States are presented in tabular form and discussed, these being based on approximately 130,000 tests by the U. S. Forest Service over a period of about fifteen years.

The data indicate that the strength of different species of wood varies in general as their specific gravity or their dry weight. Some species, however, have individual characteristics which at times cause wide deviation from this rule. Dry weight is a measure of the strength of individual pieces of any one species. No differences in mechanical properties due to a change from sapwood to heartwood have been found.

Exceedingly rapid or slow growth in conifers, such as the southern pines and Douglas fir, has usually been found to be attended by light weight and inferior mechanical properties. In the case of hardwoods, such as hickory and ash, fast-grown wood with few annual rings to the inch is generally stronger and heavier than wood of slow growth.

The effect of the locality in which trees grow on the nature of the timber produced is very complex. Variations in strength properties of the wood of a certain species attributed to difference in locality of growth are frequently exaggerated. For a single species there is likely to be a greater difference in strength between the wood of trees grown in the same locality

than between the average strength of material from different regions.

Trees growing close together and apparently under the same conditions occasionally show a difference in their mechanical properties that can not be entirely accounted for by the difference in density. Whether this difference is due to the ancestry of the tree or to some other cause, such as soil conditions, is not yet known.

The strength of small, clear pieces is greatly increased by seasoning. In large timbers, the increased strength attending a loss of moisture is mostly offset by checks and other defects developed during the seasoning process, and, therefore, under most conditions it is not considered advisable to anticipate any added strength due to seasoning.

[Agricultural Engineering Investigations at the Nebraska Station] (Nebraska Station (Lincoln) Report [1928], pp. 8-10).—The studies of poultry house ventilation and construction suggested that there is apparently no correlation between humidity and winter production of eggs in Nebraska. Egg production can be increased by artificial heat. Whether or not the increase is sufficient to warrant the expense is still a question and is somewhat dependent upon the type of heating installation used and the temperatures maintained. Air change in a unit with 4 square feet of floor space per bird has apparently no relation to egg production. Large egg production seems to go with small temperature fluctuation.

In the pump irrigation investigations a wide variation in the cost of pumping and distributing the water was noted among plants operated by stationary gasoline engines, tractors and electric motors, ranging from an estimated cost per crop acre per season as low as \$1 to as high as \$13, exclusive of investment expense. The higher cost has generally been found where an attendant was kept constantly at the plant. The expense of pumping was found to be from 2.9 to 30.16 cents per acre-foot per foot of lift, not including investment expense.

The investigations of the use of electric power on Nebraska farms showed with deep well automatic water systems a current consumption varying from 0.083 to 2.012 kilowatt-hours per 1,000 gallons per cubic foot of lift. With shallow-well automatic water systems the current consumed was 0.024 kilowatt-hour per 1,000 gallons per foot of total maximum head. A survey of the use of small unit light plants on farms showed among other things that the life of the battery is not shortened if the current is used for a number of different things rather than for light only.

Observations of electrically operated refrigerators showed a range of from 0.1471 kilowatt-hour per day per cubic foot of food space to 0.3846 kilowatt-hour per day per cubic foot, depending on the time of years, location, usage and the like.

Earth Pressure Experiments on Culvert Pipe. G. M. Braune, W. Cain, and H. F. Janda (U. S. Department of Agriculture, Public Roads, 10 (1929), No. 9, pp. 153-176, figs. 37).—The results of experiments relating to earth pressures on culvert pipe conducted by the University of North Carolina in cooperation with the North Carolina highway commission and the U.S.D.A. bureau of public roads are presented in considerable detail. The tests were conducted on 20 and 30-inch pipe of various materials, using sand and clay fills. In all tests of the first series the pipe was placed in what it termed "the condition of 50 per cent projection," that is, only one-half of the circumference of the pipe was exposed to the fill. In the first portion of this series the fill was placed over the pipe exposed in this manner, and later conditions were modified by placing and compacting a portion of the fill and then excavating a narrow trench to expose the pipe in condition of 50 per cent projection. The trench was then back filled and the fill completed in the usual manner. This was called the "trench condition." The most pertinent data were obtained in the second series of tests in which the entire surface of the pipe was exposed to the fill and information was obtained not only as to the load on the pipe but also as to the radial earth pressure and the deflection of the pipe.

In sand fill tests it was found that for equal heights of fill the pressures during removal were greater than during the filling. This was because the pipe was already deflected during removal. The pressure upon the top of the pipe was lessened as the earth was removed and the pipe tended to recover its original shape. It was partially restrained by the passive pressure of the prism of earth. Thus the pipe acted as a compressed spring and exerted an upward pressure until the passive pressure could be overcome.

Tests with clay fill and 50 per cent projection showed that the pressure on the pipe was approximately equal to the weight of the earth directly over it. The pressures during removal of the fill were greater than during the filling at equal heights, as in the first test and for the same reason.

Tests with clay fill in the trench condition showed that the vertical pressures on the pipe were less than in the 50 per cent projection condition, using the same filling material.

The pressures decreased from March to the middle of August, when a total decrease of 33 per cent had taken place. After that time a slow increase occurred until at the conclusion of the test approximately one-third of the lost pressure had been

recovered. The rapid decrease in pressure may be attributed to the drying and shrinking of the initially saturated clay resulting from the summer's unusually low rainfall. The increase in pressure is probably the result of a slow failure of the trench and of an increase in moisture content of the clay during the fall and winter months. Variations in the rainfall have but little effect, if any, upon the pressure.

Tests of the transmission of pressure from concentrated loads through the fill showed a residual pressure on the pipe after the passing of the roller for the 50 per cent projection condition but not for the trench condition. The maximum increase of pressure occurred when the rear or heavy roller was directly over the center line of the culvert. The increase in pressures for low fills is quite marked. For the trench condition the increase was not marked unless one of the rollers was over the trench. It appeared that after the passage of the roller over the 7.05 and 5.4-foot fills, trench condition, there was less pressure than before. No reasonable explanation for this phenomenon was discovered.

Further tests in the trench condition of 20 and 32-inch solid plugs, 20-inch smooth iron and corrugated metal pipes, and 30-inch concrete, cast iron, steel tube, corrugated metal and smooth iron pipes showed that, except for the first few feet of fill, the load carried increases with the height of fill at a uniform rate. The data also indicate a direct relation between the vertical load and the flexibility of the pipe.

The load-deflection ratio for the rigid pipes plots approximately as a straight line throughout, whereas the deflections of the more flexible pipe increase rapidly at first and then more slowly as the side pressure increases. On the rigid pipe the radial pressure is high at the top and low at the sides. On the flexible pipe the radial pressure is slightly higher on the sides than on the top. This variation in pressure on the two pipes is to be expected when it is realized that the flexible pipe acquires its strength through side support.

An attempt was made to correlate field data with the laboratory findings. The tests were made on a section of smooth iron pipe 30 inches in diameter and having a thickness of 0.109 inches, and also on a section of steel tube 303 inches in diameter with a thickness of 0.249 inches. There was a wide discrepancy between the pressures and deflections obtained by this method and those obtained in the field, and it was decided that field conditions could not be simulated with the apparatus.

A study of the data obtained from these experiments indicates that the magnitude of the earth pressure transmitted to the pipe is to a large degree a function of the flexibility or deflection of the pipe. If the pipe is of such rigidity that its deflection is equal to the settlement of the adjacent fill, the value of the ratio of the earth pressure to the weight of the earth prism directly over the pipe will be unity; that is, the load carried by the pipe will be equal to the weight of the prism of earth vertically above the pipe. If this rigidity is increased the load carried will also be increased, whereas if the rigidity is decreased the earth pressure transmitted to the pipe will be decreased. Using a proper ratio or factor the ultimate strength of any rigid pipe as determined by the three-point bearing test can be converted into its equivalent load-carrying capacity for earth embankments. The method can not be applied to flexible types of pipe. Three-point bearing test can be converted into its equivalent load-carrying capacity for earth embankments. The method can not be applied to flexible types of pipe. Three-point bearing tests on flexible pipe when compared with actual embankment loads show that there is no one factor that can be used to determine field loading from laboratory loading. This is due to the fact that the structural strength of flexible pipe in the two or three-point bearing test is only a part of its load-carrying capacity, the remaining portion being due to side support which is developed as passive pressure on the sides of the pipe.

Two appendices on notes relative to vertical pressures on pipe culverts, and on stresses and deflections of pipe culverts are included.

Book Review

"Report of the Division of Water Resources"—the first biennial report of this Division to the Kansas State Board of Agriculture, covering the period from July 1, 1926 to June 30, 1928—is a statistical study of the surface waters of Kansas for the period covered. Gage height and discharge measurements on the principal streams of the state are given. Important hydraulic conversion tables and an index are also included. The 250-page volume is paper bound.

Abwasserfragen (Sewage problems) is a booklet of 272 pages with many illustrations published in the German language by the Swiss Society of Agricultural Engineers. It deals with all sewage problems in agricultural engineering. Copies of this booklet may be obtained by mailing \$1 (postage included) to: Mr. O. Kaufmann, Agricultural Engineer, Centralstrasse 28, Luzern (Switzerland).

Who's Who in Agricultural Engineering



L. C. LeBron



G. E. Martin



E. B. Doran



E. C. Easter

L. C. LeBron

Lamar Cantelou LeBron (Assoc. Mem. A.S.A.E.) is agricultural engineer for the Hercules Powder Company. In his senior year as an undergraduate majoring in agricultural engineering at Alabama Polytechnic Institute he served as a student instructor in charge of laboratory work and field exercises in drainage and terracing. Also before graduating in June 1920 he was made assistant agricultural engineer of the U. S. Veteran's Bureau Board of Vocational Training and as such gave instruction in drainage, terracing and farm machinery at Alabama Polytechnic Institute to disabled war veterans. Entering the extension service of Alabama Polytechnic Institute in 1920 as assistant agricultural engineer, he was promoted to associate agricultural engineer in 1922 and, in 1925, to agricultural engineer in charge of all agricultural engineering extension work of the state. In this position he was in charge of the distribution of surplus war explosives in Alabama. He also made a study for the Dominion of Canada and several Canadian railroads of a colonization project they were promoting. Since 1927 he has been with the Hercules company and since 1929, in his present position. He has been a member of the Society since 1920.

G. E. Martin

George Edward Martin (Assoc. Mem. A.S.A.E.) is agricultural engineering extension specialist at Oklahoma A. & M. College. He came to this country from England and after farming for eight years in southern Mississippi, studied agricultural engineering at and became a student assistant on the agricultural engineering staff of the A. & M. College of Texas, receiving his bachelor's degree in 1924. His connection with the Society dates back to student membership in his undergraduate days. Before the ink was dry on his parchment he was employed by the South Side Development Company of College Station, Texas, as assistant engineer in charge of operations in connection with its sewage disposal problems. Since making his present connection he has devoted most of his time to land reclamation, particularly soil erosion control, and is largely responsible for the saving of thousands of acres of valuable lands in Oklahoma. He is a member of and secretary of the Oklahoma Committee on Soil Conservation. In the Society he has contributed several papers on terracing and erosion control, and is a member of the executive committee of the Reclamation Division.

E. B. Doran

Edwin Beale Doran (Mem. A.S.A.E.)—chairman of the Southwest Section of the American Society of Agricultural Engineers—is professor and head of the department of agricultural engineering at Louisiana State University. He is comparatively one of the pioneers of the field as he received his bachelor's degree in 1906, having specialized in farm mechanics at the University of Illinois under Dr. E. A. White. During the summers of 1904 and 1905, he "experted" for the International Harvester Company, and for a few years after graduation traveled for the same company in the Middle West, England, France, Algeria and Argentina. After another few years in general farming he went, in 1911, to the Louisiana State University as instructor in charge of farm machinery in the department of agronomy. When a separate department of agricultural engineering was authorized in 1919, he was placed in charge of it and promoted to full professorship. With the exception of two leaves of absence he has been at the Louisiana State University for eighteen years. On one of the leaves, 1928-29, he served as part-time professor of farm mechanics at the University of Illinois and earned his master's degree in farm management. Recently the direction of Louisiana's rural electrification project has been added to his duties. He has been a member of the Society since 1917.

E. C. Easter

Everette C. Easter (Mem. A.S.A.E.) is chief agricultural engineer in charge of the rural electrification program of the Alabama Power Company. Alabama born, raised and educated, he studied agricultural engineering at Alabama Polytechnic Institute, earning his bachelor's degree in 1921 and his master's degree in 1923. From 1921 to 1927 he was on the agricultural engineering staff at Alabama Polytechnic Institute. During that time he conducted research in land clearing, made a study one summer of land clearing methods used in Wisconsin; taught farm buildings, domestic engineering, terracing and farm machinery; did extension work in farm buildings and domestic engineering, and initiated Alabama's researches in rural electrification. When, in 1927, the Alabama Power Company wanted an agricultural engineer to direct its expansion into the rural field it picked him as the man for the job. He served as secretary of the Southern Section of the A.S.A.E. in 1929 and is now its vice-chairman.

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RAYMOND OLNEY, Editor

R. A. Palmer, Assistant Editor

Fatigue Studies

IN THEIR attempt to improve riding qualities of automobiles, automotive engineers have sought to replace the empirical methods of the past with scientific methods. A committee of the Society of Automotive Engineers has under way, toward this end, a definite research project. In this project it has been found necessary to get basic data which will prove broadly useful to all engineers. They have proceeded to get this information with commendable spirit.

Comfort is a difficult quality to hold a yardstick to, but it is closely associated with fatigue which can be measured through physiological conditions in various ways. So the automotive engineers have put a noted medical doctor and psychologist to work devising apparatus and methods for testing fatigue. The rate of basal metabolism, carbon dioxide combining power of the blood, number checking, and balancing on a wobblemeter have proven significant, and several other tests are being studied further.

When these tests are perfected sufficiently the next step will be to test the influence on fatigue of various positions, motions and other factors which enter into the comfort of the automobile ride. Armed with this information automotive engineers can design to minimize the fatigue-producing factors; to maximize the comfort-producing factors.

Also armed with this information, augmented by data on fatigue for other operations and performances, other engineers can not only improve their products but can make more efficient use of labor and machinery. Fatigue causes discomfort, indifference and a measurable decrease in the speed of physical reaction, balancing power and accuracy in mental checking of details. These conditions directly affect the amount and quality of work done, as well as accident hazards. They are a factor of waste in the labor cost item.

Expensive and highly efficient machinery has been made available to increase the productivity of labor. Labor has been encouraged to use it efficiently through complicated pay systems based on piecework, bonuses, fines, etc. However, where "the spirit is willing but the flesh is weak" not much increase in efficiency can result from this practice of baiting. Efficiency needs to be made

physiologically possible as well as economically desirable. The S.A.E. study of fatigue opens the way.

In agriculture fatigue is of concern both to the large-scale farmer with an industrial labor problem and to the small farmer who is his own taskmaster. In agriculture as elsewhere human energy is the most expensive form of power. Much has been done to relieve farmers from having to use their energy as beasts of burden. The next logical step will be to relieve them from unnecessary waste of energy in directing the operation of machines and animals in doing their work. If riding in a modern automobile involves unnecessary fatigue, it is safe to assume that the same is true of the operation of even the most modern farm machinery. We call to mind immediately the pressed steel seat upholstery, the lack or inadequacy of springs, and the placing of levers, pedals and other controls. The same scientific data needed as a basis for auto-riding comfort is also needed as a basis for the design of farm machinery which will minimize operator fatigue.

Progressive farmers will soon be demanding that type of equipment. Agricultural engineers will do well to keep in touch with fatigue test methods and with test data with a view to conducting further tests of their own if necessary and to considering the results as an important factor in farm equipment design.

Liberal Views on Engineering

PRESIDENT HOOVER, when inaugurating the census, gave his vocation as "engineer." In so doing he gave precedent to the modern viewpoint that engineering is not so much a type of work dealing with power and materials as it is a manner of approach to and solution of concrete problems.

William E. Wickenden, leading engineering educator, president of Case School of Applied Science, has recently expressed this and related views worth the attention of agricultural engineers. According to him, "The engineer's job is to solve any kind of concrete problem by using the resources of science under strict economic control. . . . Seven steps are involved: (1) Mastering the laws which govern the problem; (2) getting the facts and defining the problem; (3) analyzing the ways of solving the problem; (4) counting the cost and estimating the returns on the possible solutions; (5) selecting the plan which promises the best ratio of utility to cost; (6) reducing this plan of action to a systematic, detailed program of procedure; and (7) getting it done.

From this viewpoint Dr. Wickenden sees opportunities for the engineer in the whole panorama of civilization. To him engineering is inevitably an expanding influence. "If engineering is good for manufacturing and mining why not for farming and housekeeping? If it can cut production costs, why not the cost of distribution? If it solves the problem of fuel, why not that of food? The time is at hand to incorporate the biological sciences into engineering." It is regrettable that Dr. Wickenden is apparently not familiar with the work agricultural engineers are doing and not in sympathy with the degree of specialization which we represent. However, that is aside from the point. The significant thing is his viewpoint on engineering as a method of approach.

Training men to approach problems in the engineering way requires integral education in culture and technique. Technique is the badge of the profession; culture, the expansive attitude toward civilization and its problems, determines the level to which one may rise in the profession. The elements of technique can be ingrained in a few years; perfected throughout a lifetime. Only the seed of culture can be sown in collegiate years. Continued study is necessary to develop it in the engineer sufficiently to fit him for the higher levels of the profession. Adult education must take a place of increasing importance in the development of engineers.

A. S. A. E. and Related Activities

24th Annual Meeting Program

of the American Society of Agricultural Engineers
Le Claire Hotel, Moline, Ill., June 16-19, 1930

First Day — Monday, June 16

Forenoon — 9:00 to 12:00 — College Division Session
E. R. Jones, chairman, presiding

1. The Extension Man's Opportunity Compared to that of Another College Worker—Ivan D. Wood, University of Nebraska
2. An Agricultural Engineering Fellowship in Teaching Methods—Deane G. Carter, University of Arkansas
3. Agricultural Engineering Courses to Train Smith-Hughes Teachers—A. Carnes, Alabama Polytechnic Institute
4. Training Men for Research in Agricultural Engineering—J. B. Davidson, Iowa State College
5. Reports of Committees
6. Business session

Afternoon — 1:30 to 5:30 — Field Demonstrations of Farm Machinery

Evening — 7:30 — Extension Agricultural Engineers Session

Second Day — Tuesday, June 17

Forenoon — 9:30 to 12:00 — General Session
W. G. Kaiser, president, presiding

1. Meeting called to order by F. A. Wirt, chairman, Meetings Committee
2. Address of Welcome, C. W. Sandstrom, mayor of Moline
3. Greetings and announcements by R. B. Lourie, general chairman, Committee on Arrangements
4. The President's Annual Address — W. G. Kaiser, agricultural engineer, Portland Cement Association
5. "Scientific Research in Agriculture"—Dr. A. F. Woods, director of scientific work, U. S. Department of Agriculture
6. "Engineering Research"—C. F. Kettering, president, General Motors Research Corporation

Afternoon — 1:30 to 5:30 — Field Demonstrations of Farm Machinery

Evening — 7:00 — Business Sessions

1. A.S.A.E. Annual Business Meeting
2. Technical Division Business Sessions
 - (a) Power and Machinery Division—R. U. Blasingame, chairman
 - (b) Rural Electric Division—E. E. Brackett, chairman
 - (c) Structures Division—J. L. Strahan, chairman
 - (d) Land Reclamation Division—I. D. Wood, chairman

Third Day — Wednesday, June 18

Forenoon — 9:30 to 12:00 — General Session
W. G. Kaiser, president, presiding

1. "Agricultural Engineering Research"—R. W. Trullinger, senior agricultural engineer, Office of Experiment Stations, U. S. Department of Agriculture
2. "The Engineer in Tillage Research"—H. B. Walker, agricultural engineer, California Agricultural Experiment Station
3. "Industrial Uses for Agricultural Products, By-Products and Wastes"—Dr. R. A. Clemen, associate director, livestock bureau, Armour & Company
4. "Influence of Farm Machinery on the Development of America"—F. A. Wirt, agricultural engineer, J. I. Case Company

Afternoon — 1:30 to 5:30 — Sight Seeing and Factory Inspection Trips

Evening — 7:30 — A.S.A.E. Annual Banquet
L. J. Fletcher, toastmaster

Fourth Day — Thursday, June 19

Forenoon — 9:30 to 12:00 — General Session
W. G. Kaiser, president, presiding

1. "Engineers, Farmers and Tomorrow"—Wheeler McMillen, associate editor, "The Country Home"
2. SYMPOSIUM: "The All-Purpose Tractor in Corn Production"—A contribution of the A.S.A.E. Committee on Row Crop Management
 - (a) "Handling Large Yields of Corn with Machinery"—Ira C. Marshall, Ohio farmer and world's champion corn grower
 - (b) "Corn Growing—Usual vs. Corn Borer Conditions"—R. H. Wileman, agricultural engineer, Purdue University
 - (c) "Practical Motorization of the Corn Crop"—J. Leo Ahart, agricultural engineer and Iowa farmer
 - (d) "Corn Crop Production Costs"—R. I. Shawl, agricultural engineer, University of Illinois
 - (e) "Management of a Motorized Corn Farm"—E. M. Mervine, agricultural engineer, Iowa State College
3. Installation of new Society officers

Afternoon — 1:30 to 5:30 — Sight Seeing and Factory Inspection Trips

Spring Meeting of Pacific Coast Section Held at Corvallis

POWER and machinery was the subject of interest at the opening session Friday afternoon when the Pacific Coast Section of A.S.A.E. held its spring meeting at Corvallis, Oregon, May 2 and 3. Those who arrived in time enjoyed an informal luncheon on the campus of Oregon State College before the meeting opened. Following an address of welcome by President W. J. Kerr of Oregon State College, W. L. Paul of the John Deere Plow Works at San Francisco and chairman of the section, presented a paper on "Farm Implement Adjustments." F. E. Price, project leader for the Oregon C.R.E.A., presented a paper on "Forage Preparation and Handling on the Farm" which was discussed by H. E. Selby of the department of farm management, Oregon State College. Another particularly interesting paper was presented at this session by C. C. Johnson, also of the local agricultural engineering department. It was entitled "The Use of Hard Alloys on Wearing Parts of Farm Machinery."

For their evening session the section joined with the Oregon lumber manufacturers and retailers in a banquet and farm buildings program. Max E. Cook, farmstead engineer, California Redwood Association, talked on "The Development of Better Farm Structures." "The Interdependence of Industry and Agriculture" was the subject of another talk by O. M. Plummer, general manager, Pacific International Livestock Exposition.

With a few agronomists and soils experts present to present their points of view the Saturday morning session was given entirely to a consideration of tillage. Papers and discussions covered the results of tillage experiments on Oregon wheat lands, tillage experiments in Idaho, tillage power, tillage implements, tillage of field crops, tillage of orchard crops, and soils and tillage. H. B. Walker, head of the division of agricultural engineering, University of California, and chairman for the session, brought it to close with an outline of the Section's views on tillage problems. H. S. Rogers, dean of engineering, Oregon State College, was the speaker at the Saturday noon luncheon of the Section. During the afternoon the reclamation men had their inning. Papers were presented on pumping from wells, geological studies of ground water for irrigation, and refinancing of irrigation and drainage districts. The papers were followed by discussions. M. R. Lewis, of the department of soils, Oregon State College, and the division of agricultural engineering, U.S.D.A., was chairman of the session.

Oklahoma Student Branch Approved

THE A.S.A.E. Council has recently voted to recognize as a student branch of the Society the local organization of ten student members of A.S.A.E. at Oklahoma A. & M. College. The group has adopted a constitution closely following the model constitution for student branches furnished by the Society. Charter members of the new branch are as follows: J. W. Slosser, Victor J. Simpson, Floyd Frazier, Maurice Cox, C. N. Stephanon, V. W. West, Fred Lynch, Murray Cox, Merle Baldwin and Cecil Rhodes.

Missouri Holds Farm Building School

FARMERS, lumber dealers and others in the "Show Me" state who are interested in farm structures gathered at the University of Missouri April 17 and 18 to be shown things about farm building design and construction. Several A.S.A.E. members in the department of agricultural engineering at the University of Missouri and some from out of the state contributed to the program.

J. C. Wooley, chairman of the department of agricultural engineering, University of Missouri, talked on "Our Research Program in Farm Buildings," on "Efficient Arrangement" and also on "Design of Buildings for the Dairy Farm," "New Problems in Machinery Storage," and "Use of Equipment" were the titles of contributions by M. M. Jones, also of the agricultural engineering department at Columbia.

A feature of the program was a symposium on "Increasing the Efficiency of Farm Buildings." Two of the contributions, "Efficient Arrangement" and "Use of Equipment," have already been mentioned. R. R. Parks, rural electric leader in Missouri, made a contribution on "Use of Power and Light" and R. W. Oberlin, also of the Missouri agricultural engineering department, talked on "Use of Paint."

Out-of-state speakers included D. G. Carter, professor of agricultural engineering at the University of Arkansas, who talked on "Structural Requirements of Farm Buildings" and on "The Modern Farm Home," and F. A. Lyman, agricultural engineer and manager of the Farm Fence Institute, who called attention to problems in farm fencing.

On the second afternoon of the meeting an hour was given to the subject of erosion control. C. K. Shedd, agricultural engineer, division of agricultural engineering, U. S.D.A., contributed to this part of the program.

The group also toured the campus, had a banquet at the Tiger Hotel and had their picture taken.

American Engineering Council

THE National Hydraulic Laboratory Bill has passed both the House and the Senate with practically unanimous support. Slight differences in the two bills necessitate a joint conference but they will undoubtedly be ironed out and the law be made effective in a few weeks. This will authorize the construction and installation of \$350,000 worth of buildings and equipment for hydraulic investigations on the site and under the direction of the Bureau of Standards.

Hearings in February of the House of Representatives' flood control committee have recently been published. The 470 pages of testimony of thirty-seven men mostly condemned the Mississippi flood control project adopted in 1928 and demand remedial legislation. Harry Jacobs, chief state engineer of Louisiana, presented a new plan to provide for storage reservoirs as well as diversion of water. A. B. B. Harris, consulting engineer of Richmond, Virginia, criticized the Bonnet Carre spillway and suggested a different plan and location for which he claimed advantages. General Lytle Brown, chief of engineers, is having made a complete new study of the situation and will report to the President and Congress as soon as possible.

President Hoover has signed the Public Health Bill,

providing for the coordination of U. S. government public health activities. Of particular interest to engineers—the bill elevates sanitary engineers in the Public Health Service to equal rank with the medical profession.

Agricultural Engineers to Meet in First Extension Conference

COOPERATIVE extension specialists in agricultural engineering will hold their first national conference at Urbana, Ill., June 11 to 14. The program includes discussion of extension methods and plans for developing agricultural engineering as it relates to the farm water supply, farm machinery, control of soil erosion, and related subjects. The engineers will also discuss plans for contacts both with adults and with young people.

These specialists are members of the organization in which the state agricultural colleges and the Federal Department of Agriculture cooperate to make the results of agricultural research available to farmers as quickly as possible. The increase of interest in the agricultural engineering phase of this cooperative extension work is indicated by the increase in funds made available for this line of work. In 1915 about \$13,000 was expended in extension of agricultural engineering information. Nearly \$200,000 is available for this purpose for 1930. Twenty-five of the state extension services now employ one or more agricultural engineering specialists. Reports to L. A. Jones, agricultural engineering specialist in the Extension Service of the U. S. Department of Agriculture, indicate that practically all of these States will be represented at the Urbana meeting.

Personals of A.S.A.E. Members

Deane G. Carter, professor of agricultural engineering, University of Arkansas, was elected to the office of High Scribe in the Alpha Zeta Fraternity during the biennial convocation of the fraternity at Louisville, Kentucky, December 31. This office makes him a member of the High Council for the next four years.

Geo. W. Iverson, formerly supervisor of agricultural sales, eastern division, of the Caterpillar Tractor Company, has been promoted to the position of assistant sales manager, of the eastern division, of the company, and will have charge of the territory included in northwest United States and western Canada to the Rocky Mountains.

Ove F. Jensen, assistant director, Soil Improvement Work, National Fertilizer Association, addressed the Purdue University annual agricultural conference at Lafayette, Indiana, January 14, on the subject, "Methods and Equipment for Applying Fertilizers." This paper is available in the form of a reprint and may be secured from the Chicago office of the Association, 2125 Daily News Building, Chicago, Illinois.

M. A. R. Kelley, associate agricultural engineer, Division of Agricultural Engineering, Bureau of Public Roads, U. S. Department of Agriculture, is author of Bulletin No. 67, issued by the Virginia Truck Experiment Station, entitled "Design and Operation of Commercial Sweet Potato Storage Houses." The investigations upon which this bulletin is based were conducted cooperatively by the U.S.D.A. Division of Agricultural Engineering and the Virginia Truck Experiment Station.

George F. Krogh, technical draftsman and assistant in drainage, division of agricultural engineering, University of Minnesota, St. Paul, was recently appointed to a position with the U. S. Engineer's office at Sacramento, Calif.

Aubrey L. Sharp has resigned his position with the Lancetille Experiment Station, Tela Railroad Company, Tela, Honduras, to accept one in the Division of Agricultural Engineering, Bureau of Public Roads, U. S. Department of Agriculture. He will be engaged in research work on farm machinery for the control of the European corn borer.

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NOTHING ROLLS LIKE A BALL

C. K. Shedd, until recently extension agricultural engineer, University of Missouri, is now agricultural engineer with the Division of Agricultural Engineering, U.S.D.A. Bureau of Public Roads, and is located at Bethany Missouri.

Applicants for Membership

The following is a list of applicants for membership in the American Society of Agricultural Engineers received since the publication of the March issue of AGRICULTURAL ENGINEERING. Members of the Society are urged to send information relative to applicants for consideration of the Council prior to election.

Joy E. Badley, agricultural sales department, Caterpillar Tractor Company, San Leandro, Calif.

Charles H. Brown, president, Brown Tool Co., Inc., Breckenridge, Tex.

Ellis G. Diseker, assistant agricultural engineer, Alabama Polytechnic Institute, Auburn, Ala.

Marvin B. Fox, farmer, Waukegan, Ia.

John S. Franco, manager tractor department, National Brake & Electric Co., Milwaukee, Wis.

William E. Ghent, secretary, Boggs Mfg. Corp. and Boggs Plow Co., Inc., Atlanta, N. Y.

William H. Gregory, Jr., assistant extension agricultural engineer, Alabama Extension Service, Auburn, Ala.

Joseph E. Murphy, production manager, The Minneapolis Tribune, Minneapolis, Minn.

Hickman Price, Jr., farmer, Amarillo, Tex.

Bertram E. Skinner, assistant advertising manager, J. I. Case Company, Racine, Wis.

Wallace A. Thexton, rural service department, General Electric Supply Corp., St. Paul, Minn.

Ben G. Van Zee, research fellow in agricultural engineering, Iowa State College, Ames, Ia.

John B. Wilson, extension agricultural engineer, Alabama Polytechnic Institute, Auburn, Ala.

Transfer of Grade

John W. Randolph, assistant professor, Alabama Polytechnic Institute, Auburn, Ala. (Associate Member to Member.)

New A.S.A.E. Members

John Bird, Jr., advertising manager, The Wheat Farming Company, Topeka, Kan.

George C. Brooks, manager of rural department, Empire Gas & Electric Co., Waterloo, N. Y.

Wilbur Drake, graduate fellow, Iowa State College, Ames, Ia.

Albert R. Fairchild, general station sales engineer, Westinghouse Electric & Mfg. Co., Glenside, Pa.

Albert B. Hanse, engineer, J. I. Case Co., Racine, Wis.

Fred W. Hawthorn, farmer, Castana, Ia.

Louie T. Jessup, associate drainage engineer, U. S. Department of Agriculture, Yakima, Wash.

David A. Milligan, assistant agricultural engineer, Cleveland Tractor Co., Cleveland, Ohio.

Charles F. Moreland, in charge of water heater sales, Edison General Electric Appliance Co., Chicago, Ill.

Robert S. Overstreet, agricultural engineer, Idaho Power Co., Boise, Ida.

Frazier Rogers, professor of agricultural engineering, University of Florida, Gainesville, Fla.

Louis C. Thomsen, assistant professor of dairy husbandry, University of Wisconsin, Madison, Wis.

Orville J. Trenary, instructor, University of Nebraska, Lincoln, Neb.

Employment Bulletin

An employment service is conducted by the American Society of Agricultural Engineers for the special benefit of its members. Only Society members in good standing are privileged to insert notices in the "Men Available" section of this bulletin, and to apply for positions advertised in the "Positions Open" section. Non-members as well as members, seeking men to fill positions, are privileged to insert notices in the "Positions Open" section and to be referred to persons listed in the "Men Available" section. Notices in both the "Men Available" and "Positions Open" sections will be inserted for one month only and will thereafter be discontinued, unless additional insertions are requested. Copy for notices must be received at the headquarters of the Society not later than the 20th of the month preceding date of issue. The form of notice should be such that the initial words indicate the classification. There is no charge for this service.

Men Available

SOILS EXPERT, with national reputation, for many years engaged in practical research work in soil manipulation improvement and in the development of tillage equipment, desires connection with farm equipment manufacturer, with large farming enterprise, or with banking, insurance or mortgage company where his ability and experience in building up worn-out lands for profitable production is needed. MA-164.

AGRICULTURAL ENGINEER now employed as a teacher of vocational agriculture desires a position as teacher or research worker in agricultural engineering, preferably at a southern college. Have had two years experience in college teaching and while in present work have had outstanding experience in farm shop work and farm buildings. Age 33. Married. MA-170.

RURAL SERVICE ENGINEER, completing a fellowship in agricultural engineering in June, 1930. Graduate in electrical engineering 1928 and will have M. S. in agricultural engineering in June 1930. Two years experience in research work in rural electrification. American, unmarried, age 23. Junior Member A.S.A.E. Position with power or electrical appliance company preferred. MA-172.

MECHANICAL ENGINEER, ten years experience draftsman and designer on tractors, combined harvesters and kindred machines. Expert knowledge tools, jigs and fixtures for quantity production. Field experience. MA-174.

Positions Open

AGRICULTURAL ENGINEER wanted to fill position as instructor or assistant professor in the department of agricultural engineering of one of the land grant colleges of the Northwest. A recent graduate in agricultural engineering qualified for rural electrification and power farming with farm and practical experience is desired. Opportunity offered for research work and for participation in experiment station and extension service projects. Teaching work required will be largely in service courses in agricultural engineering. Minimum salary \$1800 to \$2100 per year on twelve months basis with one month vacation. PO-155.

AGRICULTURAL ENGINEER wanted to fill position as instructor or assistant professor in the department of agricultural engineering of one of the land grant colleges of the Northwest. A recent graduate in agricultural engineering qualified for land reclamation, especially irrigation and drainage, with irrigation farming and project management experience desired. Opportunity offered for research work and for participation in experiment station and extension service projects. Teaching work required will be largely in service courses in agricultural engineering. Minimum salary \$1800 to \$2100 per year on twelve months basis with one month vacation. PO-169.

JUNIOR ENGINEER wanted by eastern utility for electric power sales in rural communities, including small commercial development. Should have an agricultural background and be a graduate of a recognized technical college. Good opportunity for advancement. Please enclose recent picture and state age, education, experience and salary desired. PO-170.

AGRICULTURAL ENGINEER wanted to fill position as instructor and research worker in rural electrification with the department of agricultural engineering at the Virginia Polytechnic Institute. Man should preferably have a professional engineering training and some experience in research or teaching. Opportunity for graduate study is offered. Apply direct to Prof. Chas. E. Seitz, V.P.I., Blacksburg, Virginia, for full particulars.

